Fabrication and experimental analysis of banana fibers reinforced polymer composite filled with Aluminium-powder filler for automotive body

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ABSTRACT
The rising concern of environmental related issues and attention given to green and clean composite materials and the need of finding realistic alternative to replace heavy metals have led researchers to find for alternative natural fiber reinforced polymer composites. The main objective of this study was to introduce new green composite materials from abundant waste resource of banana stem that have high mechanical and physical properties fiber used for automotive companies. The composite was fabricated from banana fiber filled Al-powder filler through resin-hardener mixture by simple hand lay-up technique followed by compression molding technique to obtain high mechanical and physical properties. The samples fabrication procedure carried out on fixed weight percentage of banana fibers by varying Al-powder filler weight percentage to see its effect of mechanical and physical properties. Four samples i.e., Banana fiber reinforced polymer composite (sample A), banana fiber reinforced polymer filled 5wt% of Al-powder filler (sample B), banana fiber reinforced polymer composite filled 10wt% Al-powder filler (sample C) and banana fiber reinforced polymer composite filled 15wt% Al-powder filler (Sample D) was produced by fixing banana fibers 10 weight ratio and 0wt%, 5wt%, 10wt% and 15wt% of Al-powder filler respectively. Then, tensile strength, density, micro hardiness, water absorption percentage and Microstructure were conducted according to ISO and ASTM standards. The results show that steady tensile strength increment is obtained by adding Al-powder up to 10wt%. Beyond this wt% of Al-powder tensile strength decreased. Density of composite samples filled Al-powder increases as the wt% of Al-powder increase. Microstructure of sample C exhibits superior distribution of Al-powder than other samples. As Al-powder increase the water absorption of the samples decreases. Micro structure of the fabricated samples shows best Al-powder distribution throughout the composites. Overall optimal mechanical and physical properties obtained at sample C with highest tensile stress, less water absorption, moderate density, microstructure and micro-hardness when compared to other samples.

Keywords: Banana fibers; Aluminum Powder; Resin; Mechanical Properties.

1. INTRODUCTION

1.1. Background

According to [3] increasing consideration towards sustainable progress and environment awareness forces scholars to discover more on the green biodegradable materials based on agricultural trashes. The rising environmental concerns, global warming, waste controlling concerns, declining fossil resources, as well as escalating oil prices have resulted in increase in research for innovative materials that are friendly to our health besides environmental concern. Green products are being increasingly promoted for sustainable development [21].

A new trend in engineering research is to replace heavy metals with polymer material reinforced with natural fibers such as different plants, animal and wood fibers. Many researchers have focused to replace heavy metals by some materials with low density and high strength. Thus, the use of polymers in various applications has grown rapidly. Now a day the application of polymer grounded products can be found from household utilities to aerospace applications [10].

Moreover, automotive as well as packaging companies are demanding a change of their design from oil-derived polymers and mineral underpinning materials to natural materials focusing the recyclability or else biodegradability of green products at the termination of life [1].

[8] reported that the furthermost important benefits of natural fibers relate to environmental issues: they are biodegradable as well as carbon positive, subsequently they absorb more carbon dioxide than they produce [5]. The fibers from the natural sources provide certain advantages over synthetic reinforcement fibers for instance low cost, non-toxicity, comparable strength, small density; also, minimum waste disposal problems [18]. Natural fiber reinforced thermoplastic composites exhibits supremacy

over conventional materials outstanding to ease of processing, fast fabrication cycling and low tooling cost, thus making them most suitable materials for automobile and electrical industries [12]. In comparison with synthetic fibers, natural fibers exist low in cost, low density, and have very much specific property [20].

According to [14] report high level of moisture absorption, poor wettability, inadequate adhesion and de-bonding are the main disadvantages of natural fibers reinforced composites. Natural fibers are also having some draw backs, such as large variations in mechanical properties, sensitivity to humidity and UV radiation plus low resistance to impact [4].

Banana fibers have good specific strength properties comparable to those of conventional materials, similar to glass fibers [19]. Ethiopia as a country whose economic sector depends on agricultural products has abundant potential to develop and utilize fiber derived from Agricultural waste. Banana and false banana fibers which are important byproducts of farmer food processing are discarded as waste in Gurage zone [17]**.** The surplus by-products of agricultural products are abundant and quantitatively beneficial in a country like Ethiopia with its massive agricultural resources. Reducing natural assets, regulations on using synthetic resources, increasing environmental awareness and economic attentions are the major motivating forces to utilize annually renewable resources such as biomass for various industrial applications [22].

By product of the rotting process is methane gas which is some of the greenhouse gases (a pollutant). Utilization of the banana stalk fibre not only benefits the environment, but it will also reduce the overall resource consumption while sustaining national economic growth and introduction of green technology to the rural areas [2]. [4] report shows that the structure and chemical composition of natural fibers are greatly dependent on climatic condition, soil type, and age of plant and the individual characteristics of each plant variety. According to [11] report mechanical properties of lignocelluloses fibers may also vary greatly, even from same plant. This is due to several factors during the plant's life cycle, including growing circumstances, the maturity of fibers during harvesting; the ways and means used to extract the fibers, and the transportation and storage of fibers over time [6]. Alkali treatments have existed recognized effective in removing contaminations from the fiber, reducing moisture absorption and permitting mechanical bonding, and thereby improving matrix-reinforcement interaction [7].

[14] clearly reported that the use of natural fibers reduces weight by 10% and lowers the energy consumption needed for production by 80%, while the cost of the component is 5% lower than the comparable fiber glass-reinforced component [9]. According to [17] composites, the wonder material with light -weight, high strength to weight ratio and stiffness properties have come a long approach in replacing the conventional materials like metals, woods etc. The replacement of steel with composites can save 60% to 80% of component weight and 20% to 50% with the Aluminum components. The polymer fabricated composite materials use is increasing because of their light weight as well as good mechanical responses.

The most important advantages of using composites in automotive is the weight reduction as the composites are up to 35% lighter than Aluminium and 60% lighter than steel and the use of composites in automotive can clues to an overall vehicle weight reduction of up to 10%. Other classes of light weighting materials used in automotive for the "greening" of automotive industry are natural fiber reinforced composites. Replacement of glass fibers with natural fibers allows lighter components as the density of natural fibers (1.5 g/cm^3) are lower compared to glass fibers (2.5 g/cm^3) while simultaneously increasing the proportion of renewable resource content within the vehicle [13]. Composites are materials that embrace strong load carrying material (known as reinforcement) set in weaker materials (known as matrix). Reinforcement is responsible for strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) upholds the position, orientation of the reinforcement and transfers the peripheral load to the reinforcement [15].

1.2. Statement of the Problem

A process of meeting human need in manufacturing technology aims to ensure and provide the ecosystem services to the natural resources upon which the society and economy depend is called sustainable development.

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To ensure this; natural fiber as a means of usable material to engineering application is a key element. In developing country most of the time the body and spare part of automotive were imported from abroad. In Ethiopia also, the spare part and body of automotive were imported from developed country. These imported materials are heavy in weight, high in cost and have an adverse impact on the environment. On other hand Ethiopia is known as agricultural dependent country. Among many sources of agricultural product banana is one of the major sources of fruit with unusable stem of banana which is disposed as a waste in case of our country's trend, because the source of fiber in Ethiopia is related only to false banana and sisal. Therefore, the preparation of natural fibers composite using banana in aligned with automotive application will plays a vital role in manufacturing sectors. Many researchers carried out their study on natural fibers as a replacement source of material for heavy metals and glass fibers. A few researchers conducted their study to fabricate composite from natural fibers and metallic powder filler. So, this study was elaborated to a great opportunity for our country to produce automotive body from Aluminum filled banana fibers as reinforcement for better strength, long survival time, and reduced water absorption behavior of banana fibers.

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of this study is to fabricate and analyze the mechanical and physical properties of banana fibers reinforced polymer composite filled by Al-Powder filler for automotive application.

1.3.2. Specific Objectives

The specific objectives of this study are:

- To fabricate composite of banana fiber reinforced polymer composite filled Al-powder filler by hand lay-up with compression molding technique from banana fiber, resin and aluminum-powder filler for better mechanical bonding.
- To evaluate mechanical and physical properties i.e., tensile stress, density, water absorption percentage, micro-hardness and micro structure of composite fabricated from treated banana fibers filled aluminum-powder filler for the automotive body application.
- To analyze and recommend better weight ratio of banana fibers filled aluminum-powder filler samples and evaluate against previous literature. Research questions

2. MATERIALS AND METHODS

2.1. Introduction

The main objective of this study was to fabricate a new composite from banana fiber filled by Al-Powder filler and analysis its mechanical and physical properties. The samples were fabricated based on weight fraction. The procedure to fabricate laminated composite was described clearly in flow chart below.

- Banana fiber was extracted and collected from Hawassa City area. These fibers washed repeatedly by down runner water and dried in air. Banana fiber was treated by using 5% NaOH in Chemistry department laboratory, Hawassa University, Ethiopia. The pH for this amount of NaOH was measured. Then, treated fiber was washed three times till it becomes neutral by means of down runner water. Finally, it was washed by distilled water and dried in air for 48 hours.
- Unsaturated polyester resin and hardener (Catalysts) was bought form World Fiber Glass and Water Proofing Engineering Company, Addis Ababa, Ethiopia.
- Aluminum Powder filler was purchased from Germany Country online market.
- Musk, brush, gloves, roller, wax, string wood, and scissors were purchased from local pharmacy and market centers.
- Mold was prepared form Aluminium sheet to fabricate samples.
- Simple hand lay-up composite production method was used that followed by compression molding for 24 hours to remove excess resins and air bubbles.
- Treated banana fibers without/with Aluminum Powder filler was produced layer by layer through using resin by hand lay-up system and rolled by roller.
- The curing process was taken at room temperature for 48 hours.
- The fabricated sample was cut into specimens based on tests standard to obtain their mechanical and physical properties by using convectional testing machines.

- The results were analyzed and the optimal composite fabrication weight ratio was identified.

Unsaturated polyester resin and hardener was mixed based on the weight ratio. Then Al-Powder filler was added to mixture of resin and hardener according to samples based on wt% requirement. To obtain the influence of Aluminum Powder filler on banana fiber matrix weight fraction to resin-hardener mixture was carried out.

Generally, all samples were produced based on the treated fiber filled Aluminum Powder filler on four (4) different ratios to resin-hardener mixtures. The whole mixing ratio was done based on weight ratios.

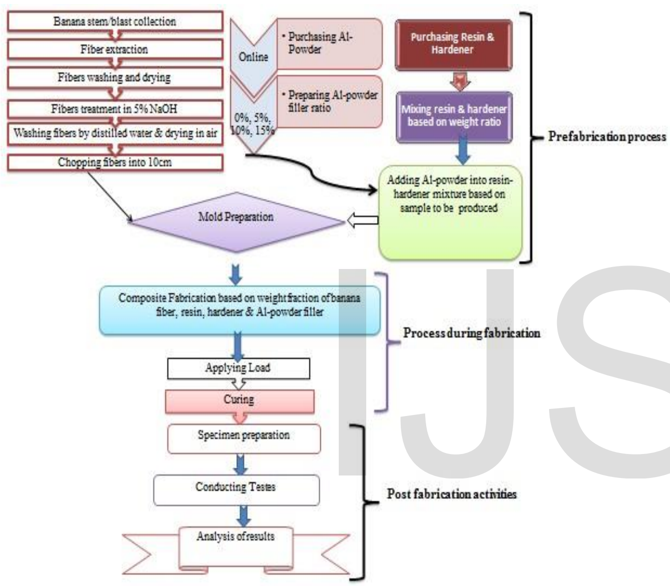

Fig 1: Flow diagram of sample prefabrication, during fabrication and post fabrication process.

2.2. Materials

Materials those used to form composites are: banana fibers, Aluminium Powder filler, unsaturated polyester resin, hardener (catalyst), and NaOH.

The equipment used to remove impurities and for mixing resin, hardener and Aluminium mixtures are comb, musk, roller, gloves and stirring wood.

2.2.1. Banana Fibers

Banana fibers were extracted from Banana stem and the extraction was done by manual/traditional method.

The extracted banana fibers were washed by down runner water and dried in Air. Combing was carried out to remove dirty and impurities. Then Banana fibers were treated by 5% NaOH to improve physical, chemical and mechanical properties of the fibers. Again, it was washed by down runner water and distilled water to neutralize the chemicals and dried in air for further process.

2.2.2. Al-Powder Filler

99.9% pure Aluminium powder of 56µm was purchased from online, Germany. It was added to resin and hardener based of weight percentage of resin and hardener mixture needed to produce laminated composite for this study. To analyze its mechanical properties effects on natural fibers; it was conducted by adding Aluminium Powder filler of 5%wt, 10%wt and 15%wt by measuring its mass on digital balance at Chemical Engineering laboratory, ASTU, Ethiopia.

2.2.3. Matrix and Hardener

Generally, polymers can be classified into two classes; thermoplastics and thermosetting. Thermoplastic materials currently control, as matrices for bio-fibers; the most frequently used thermoplastics for this purpose are polypropylene (PP), polyethylene, and poly -vinyl-chloride (PVC); while phenolic, epoxy and polyester resins are the most commonly used thermosetting matrices [17]. Unsaturated polyester resin and Catalyst were purchased from World Fiber Glass and Water Proofing Engineering Company, Addis Ababa, Ethiopia. The weight fraction of each sample resin-hardener mixture was done on digital balance at Chemical Engineering laboratory, ASTU, Ethiopia. For each sample the amount of resin-hardener used was described in table 1.

To obtain best mixture of resin-hardener and Al-powder filler mixture using measured amount of each composition play a great role. To fabricate each sample mixing resin-hardener that filled Al-powder filler was recommended based on the sample type and production amount.

Table 1: Mix batch of resin and hardener based on wt% composite

S. No:	Date	Sample	Batch No: Quantity (grm)			Cup Mass (grm)	Gross Mass (grm)
			Resin	Hardener	Al-powder (grm)		
1.	14/05/2018	A	985.84	8.86	0	5.75	1,000.45
2.	14/05/2018	B	936.55	8.37	49.292	5.75	999.962
3.	16/05/2018	C	887.26	8.87	98.584	5.75	1000.46
4.	16/05/2018	D	838.08	8.38	147.76	5.75	999.97

2.3. Chemical Treatment of Fibers

Influence of surface treatment on natural fibres improves the interfacial bond between fibre and resin thereby increases its mechanical properties. Alkali treatment of jute and banana fibre reinforced composites with 5% NaOH improves the mechanical properties of composites. Alkali treatment removes the lignin and hemicellulose content in the fibre, also decreases the spiral angle so as to increase the molecular alignment thus increasing the elastic modulus of fibre. Improvement of interfacial bonding is significant in improving mechanical properties. Alkali treatment provides finer fabric, increase crystallinity, reduction in number of defects, superior bonding and reduced moisture absorption [10]. Chemical treatment is needed to improve the mechanical properties of natural fibers. Most of the researchers use 1-10% NaOH to improve the properties. For this study 5% NaOH was used to improve Mechanical properties. Then, it was washed by down running water. Finally, it was by distilled water and cured in air for 48 hrs.

2.4. Sample Preparation Methods

The sample preparation was based on 10% fixed weight ratio of banana fiber to resin-hardener mixture. Majority of researchers focused on volume ratio of natural fibers to matrix compositions. But, some of them uses weight fraction. Again, some of them used different weight/volume fraction of natural fibers to matrix ratio; while few researchers use fixed volume/weight ratio of natural fibers to matrix to see their effect on mechanical properties. In this study, the basic focus was to see Al-powder filler effect on mechanical and physical properties of composites. So, this study was carried out on fixed weight ratio of banana fibers to variable resin hardener- Al-powder filler composition. Adding more weight ratio of banana fiber causes porous on fabricated composite and lowering weight ratio below 10 wt% reduces fiber utilization. Based on these 10 wt% of banana fibers was taken for this thesis work. Shortly, it was indicated by the following table 2

Table 2: Fabrications of Composite Samples

Sample Code	Composition (wt %)
A	Resin-hardener (90 wt %) +Banana Fiber (10 wt %) + Aluminium powder filler (0 wt%)
B	Resin-hardener (85wt %) +Banana Fiber (10wt %) + Aluminum Powder filler (5wt %)
C	Resin-hardener (80wt %) +Banana Fiber (10wt %) + Aluminum Powder filler (10wt %)
D	Resin-hardener (75wt %) +Banana Fiber (10wt %) + Aluminum Powder (15wt %)

Note: A= represented for Banana fiber reinforced Polyester matrix composite

B= Banana fiber reinforced Polyester matrix filled by 5wt % Al-powder composite.

C= Banana fiber reinforced Polyester matrix filled by 10wt % Al-powder composite.

D= Banana fiber reinforced Polyester matrix filled by 15wt % Al-powder composite.

Generally, to obtain high mechanical properties of composite, considering cause-effect plays great role. In this study, causes and parameters are considered to produce sample from banana fibers. Among many factors those affects the results of fabricated composite; I have clearly focused on some of them. The causes/parameters those should be taken into consideration during fabrications of laminated composites are as I have tried to show by below cause-effect fishbone diagram. The cause/parameters those controlled at hand lay-up process gets attention in one or more way to obtain quality product that show better mechanical and physical properties. The produced mold for sample producing were cleaned by releasing agent (wax) and dried before pouring resin-hardener mixture/resin-hardener-Aluminum powder mixture on it. The mixed resin-hardener mixture/resin-hardener-Aluminum mixture based on weight percentage which stirred manually poured on the clean mold. The treated banana fibers were distributed uniformly over resin poured on the mold in non-woven orientation. Again, resin-hardener mixture/resin hardener-Aluminum powder was poured on the banana fiber layer. The excess resin and air bubble were removed from the composites by using hand roller. It was also used to uniformly distribute mixture of resin-hardener/resin-hardener-Aluminum powder through the composites. Then, banana fiber and mixtures of resin are added till the required thickness and samples are produced. Then, it was compressed under 50kg for 24hrs to remove excess resin mixture and air bubble.

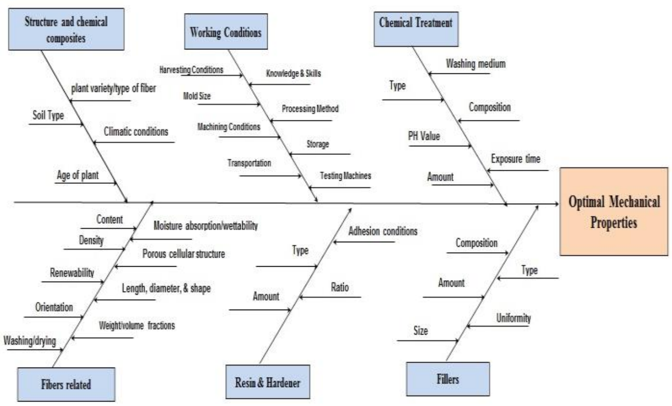

Fig 2: Fish-bone diagram of factors those affects the mechanical properties of Natural fiber reinforced composites

By considering some of these six causes those play a great role to obtain laminated composite fabricated from banana fiber reinforced polymer composite filled Aluminium powder filler optimal mechanical properties; the procedure to fabricate sample was as shown in figure 3.

Fig 3: Banana fiber reinforced polymer composite fabrication procedures

2.4.1. Mould Preparation

The mold was fabricated from Aluminum sheet of 30cmx25cmx6mm size by bending machine as shown in figure 4. The fourth direction was closed by sheet Aluminium of 5mm to obtain uniformly distributed laminated composite sample.

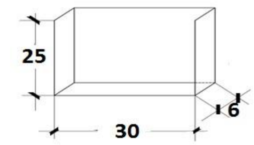

Fig 4: Mould dimension to fabricate laminated composite

2.4.2. Preparation of Banana Fibers reinforcement-resin-hardener mixture filled Al-powder filler based on weight fraction

The fiber orientation selected for this study was chopped short randomly distributed (non-woven mat) fashion because one can be fabricating easily any product from waste banana stem by this method. The fiber was chopped into 8-10cm length and randomly distributed over 120cm x 75 cm areas based on 10 wt% to resin-hardener/resin-hardener-Al-powder filler mixture. After equally distributed over the area, load was applied over fiber to hold fibers on distributed location and then chopped by scissors for four (4) samples to be produced. Each sample has three layer of banana fibers and four layers of resin-hardener/resin-hardener-Al-powder mixture. Mix by weight ratios are recommended for accuracy, especially for smaller batches of composite like this study. The mixing of small test batch is familiar to mixing and curing process before applying the whole mixture needed to produce the composite. The test batch verify that resin: hardener to Al-powder filler ratio is accurate each time. The mix by weight method is more preferable for small batch of resin to hardener that determines the proper mixing ratio for this thesis purpose. Then the proper amount of resin to hardener was added to pure and clean containers. During pouring of resin and hardener into the container; adding of the correct amount of hardener to achieve an accurate ratio was carried out. Then mixture was stirred well and cure to scrapes the sides and bottom of the container. It was stirred until the mixture is no longer hazy. Mixing takes place a few minutes depending on the batch sizes amount of Al-powder filler used per sample. 2-4-minute mix was done till uniform in color and viscosity. Then, the stirred and well mixed resin hardener/resin-hardener-Al-powder filler was poured on mold. The banana fiber was added over matrix and rolled

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well by roller. Again resin-hardener/resin-hardener-Al-powder filler was poured over banana fiber layers. By the same fashion all samples were done till the required thickness was obtained.

2.5. Experimental setups and Procedures

Specimen for Mechanical and physical tests are prepared according to dimension requirement and machines standard. Then average values are taken for analysis. For density measurement also three specimens are taken from each sample and an average result was used for analysis. Micro hardiness and water absorption tests are done on single specimens of each sample. All specimens are cut by circular cutter, grinder and Abrasive cutter.

2.5.1. Specimen preparation procedure for all Samples

Specimen for each sample was prepared based on the dimension requirements of the mechanical and physical properties test that was conducted for this study. The dimension requirement for tensile strength test on 2000kN UTM of Ethiopian Conformity Assessment Enterprise based on ISO 6892-1 was indicated by figure 5 below. Three specimens per sample was prepared by using circular cutter and grinder and finally polished by polishing paper. Specimen for compression strength test was also cut by circular cutter and grinder based on the dimension requirement. For microstructure and micro-hardness specimens are produced by using abrasive cutter.

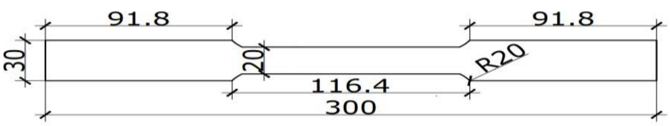

Fig 5: Specimen dimension for tensile stress measurement on UTM-2000kN machine

Fig 6: Specimen identification codes (User's code) for tensile test on UTM-2000kN

2.5.2. Testing Procedure of Specimens

The test procedure of sample was conducted by preparing specimen based on the kind of test conducted. The mechanical and physical properties test conducted in this study is indicated by Table 3 given below.

Table 3: Tests and machine on which tests was conducted

S.No	Name of the test	Name of the Machine
1	Tensile Strength	UTM-2000kN
2	Density	Water immersion method
3	Micro Hardness	Vickers Hardness Tester (HVS-50)
4	Moisture Absorption	Water immersion Method
5	Microstructure	Metallurgical Microscope

2.5.2.1. Tensile strength

Tensile stress test was done at Ethiopian Conformity Assessment Enterprise on UTM 2000Kn. It determines tensile properties of banana fiber polymer composite filled Al-Powder filler in the prepared sample plane. For all samples three specimens are prepared and average results was used for comparison of the results. The specimens were designed as: **A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2, C_3** and **D_1, D_2, D_3** based on Aluminium powder filler content and trial number for each sample.

2.5.2.2. Density measurement

Actual density (ϱ_{ce}) of the composite is determined experimentally by simple water immersion technique with the use of the sample of 30mmx30mm dimensions. Three specimens were tested per each sample and average value was taken for density analysis of each samples. Each sample is measured on digital balance at Chemistry department, Hawassa University, Ethiopia. The volume of each sample was obtained from displaced water level during immersion of composite into water.

2.5.2.3. Micro-hardness test

Hardness is the resistance of a material to deformation, indentation or scratching. The basic goal of hardness testing is to quantify the resistance of a material to plastic deformation. The indentation value has high importance for technical applications which reflects the resistance to deformation which is a complex property and related to modulus, strength, elasticity, plasticity and dimensional stability of a material. The Vickers hardness test uses square-based pyramid diamond indenter with an angle of 136^0 between the opposite faces at the vertex, which is pressed into the surface of the test piece using a prescribed force, F.

HV= Constant x Test Force/Surface Area of Indentation

$$= \frac{0.102 * 2F(\frac{\sin 136^0}{2})}{d^2} \quad \ldots\ldots (1)$$

Equation 1 above was taken from manual of HVS-50 machine of Adama Science and Technology University. The HVS-50 machine used for this project has measuring rage: 5-2900 HV, Test Force: 9.807, 49.03, 98.07, 196.1, 294.2, 490.3N, maximum height of test piece: 180mm, depth of throat: 125mm, magnifications of the measuring system: 125X, 250X and minimum scale value of the optical micrometer: 0.5μm. load used during hardiness test was 49.03 N (10kg.f) on three trails per each sample. Average result was used for comparison of HV value of all samples. The micro-hardness testing machine and abrasive cutter is shown by Figure 7 below.

Fig 7: Abrasive cutting in action (RB-203), Micro-hardness measurement under Vickers Hardness Tester (HVS-50)

2.5.2.4. Water Absorption percentage

According to literatures source moisture absorption was conducted in accordance with ASTM D570-98. Single specimens of each composite are cut and their weights are taken as per their samples. All samples were immersed into water for 8 days. Then the specimen is removed from water and cleaned by dry materials and their weights are measured within 24hrs difference. The measurement was taken immediately after the specimens removed from immersed water, dried by dry materials and exposed to air. The specimen size prepared was 30mmx30mm. the following equation was obtained from [10].

$$\% \text{ Water Absorption} = \frac{Wt - Wo}{Wo} * 100 = \frac{mw - ma}{ma} * 100 \quad \ldots (2)$$

Where, wt is weight of wet sample

w_o is weight of dry sample

m_w is mass of wet sample

m_a is mass of dry sample.

3. RESULTS AND DISCUSSIONS

3.1. Introduction

Based on the objectives and methodology of this study the results of mechanical properties and physical properties are described by Table 4. The interpretation and analysis were done by Minitab software. The better composition of the sample was discussed based on result obtained from experiment.

Table 4: Samples result finding of tensile strength and density

Sample code	Tensile strength (MPa)	Density (g/cm³)
Treated banana fiber composite with unsaturated polyester resin (90wt %) +banana fiber (10wt %)		
A_1	28.1	1.031
A_2	19.8	1.098
A_3	23.7	1.079
Average	**23.87**	**1.069**
Treated banana fiber composite with unsaturated polyester resin (85wt %) +banana fiber (10wt %) + Aluminum Powder (5wt %)		
B_1	32.8	1.096
B_2	32.3	1.095
B_3	23.7	1.096
Average	**29.6**	**1.096**
Treated banana fiber composite with unsaturated polyester resin (80wt %) +banana fiber (10wt %) + Aluminum Powder (10wt %)		
C_1	42.1	1.075
C_2	24.7	1.138
C_3	32.4	1.239
Average	**33.07**	**1.151**
Treated banana fiber composite with unsaturated polyester resin (75wt %) +banana fiber (10wt %) + Aluminum Powder (15wt %)		
D_1	25.3	1.154
D_2	35.6	1.178
D_3	30.9	1.244
Average	**30.6**	**1.192**

3.2. Analysis of Tensile Strength

Based on fabricated composite average tensile stress value sample C (banana fiber reinforced polymer composite filled 10 wt% Al-powder filler) has higher tensile stress. It was clearly seen as Al-powder filler increase up to 10 wt% tensile strength increases. But adding more wt% Al-powder filler results to decrease the tensile strength of the composite. Sample A (banana fiber reinforced composite polymer) has lower tensile strength than Al-powder filled composites. Shortly, from this study point of view Sample A (banana fiber reinforced composite that do not have Al-powder filler) exhibits lower tensile stress. Sample B and Sample D have moderate tensile stress when compared to unfilled banana fiber reinforced polymer composite.

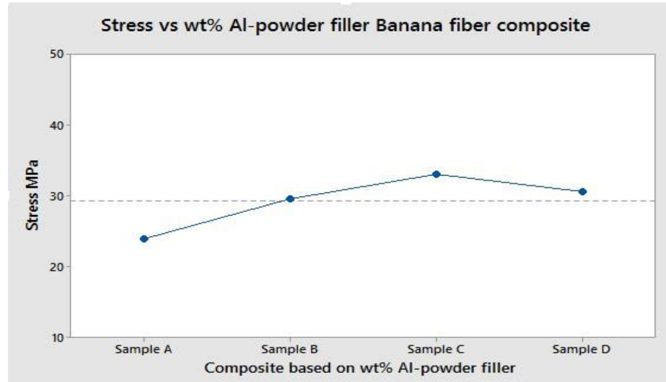

Fig 8: Tensile stress vs composite samples based on wt% of Al-powder filler

3.3. Density

Density of banana fiber reinforced composite increases as wt% of Al-powder filler increases. The result of Sample D (banana fiber reinforced polymer composite filled 15 wt% Al-powder filler) indicates higher density than other sample results. Sample A has lower density than other composite samples those filled Al-powder based on wt% Al-powder filler. Sample B and Sample C have medium density. As the main objective of the study is reducing the weight and density of automotive body component, increasing Al-powder filler beyond some wt% is not recommended.

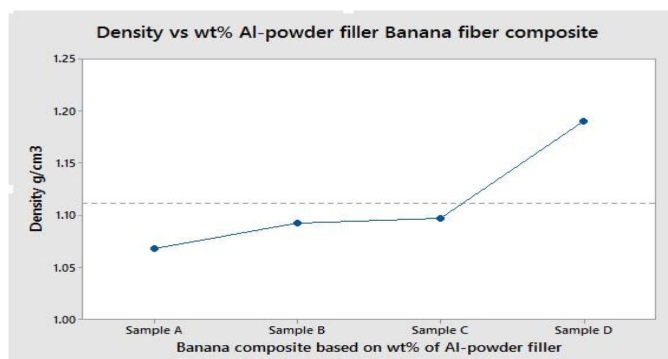

Fig 9: Density vs wt% Al-powder filler Banana fiber composite

3.4. Micro-hardness

The result of micro-hardness of each sample was tabulated by table 5.

Table 5: Samples micro-hardness results of banana fiber reinforced polymer composite filled Al-powder filler.

Composite	Trial 1	Trial 2	Trial 3	Average
A	293.8	212.4	198.3	234.83
B	136.6	191.0	207.5	178.37
C	132.0	206.1	148.4	162.17
D	133.2	123.2	207.3	154.57

The comparison for each sample is analyzed by taking average value of three trial value of specimens. The result of micro hardiness indicates that as wt% Al-powder filler increases the micro hardiness of samples was decreases. Sample A has higher micro hardiness value while sample D has the lower HV value. So, as the Al-powder filler wt% increase the micro hardiness of composite fabricated from 10 wt% of banana fiber decreases in this study. The resistance to load decrease by increasing Al-powder wt% amount.

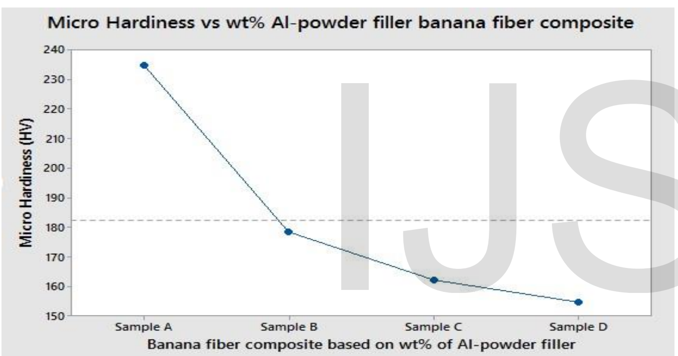

Fig 10: Micro-hardness vs wt% Al-powder filler Banana fiber composite

3.5. Water Absorption Percentage

Water absorption percentage analyzed for each day and averagely for 196 hours. Water absorption percentage of all sample was tabulated and analyzed individually by 24 hours' time interval for 8 days. The comparison is done on average value of each samples.

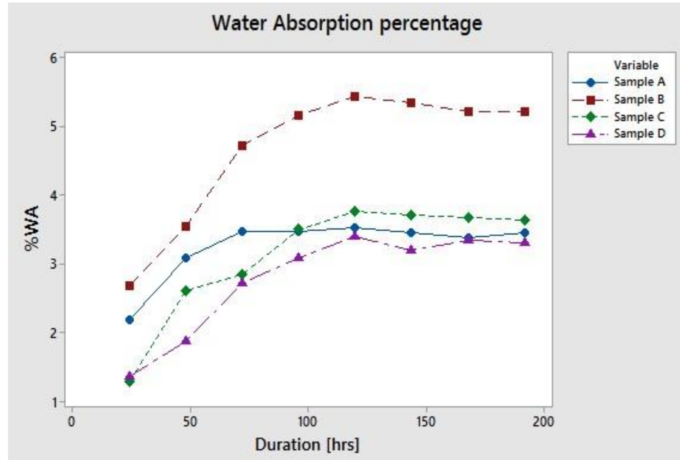

Fig 11: Water absorption percentage vs duration for 8 days

Sample A, sample C and Sample D have lower water absorption percentage than sample B. This shows that over 192 hours sample D shows lowest water absorption percentage than other samples. As Al-powder increase the water absorption percentage decreases. Lower water absorption is more recommended for automotive body.

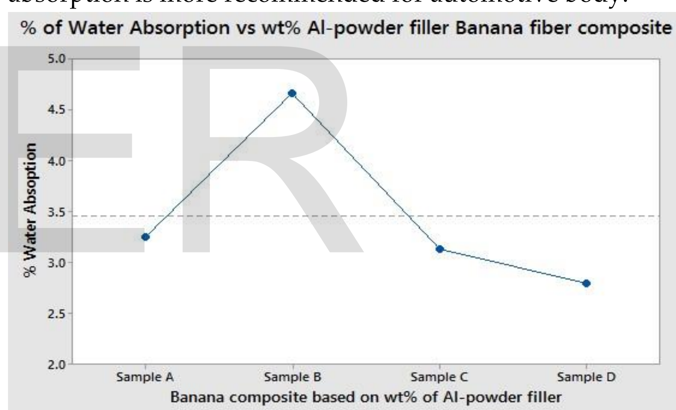

Fig 12: WA% vs wt% of Al-powder filler Banana fiber composite

From the result point of view, as wt% Al-powder filler increases the water absorption percentage of the samples decrease. Sample B has higher water absorption percentage which followed by sample A. Sample C and D have less water absorption properties. Higher water absorption percentage is not recommended for automotive body and other industry applications. So, sample D and C are suitable for automotive body. As compared to unfilled banana fiber, those Al-powder filled have lower water absorption percentage.

3.6. Microstructure

The microstructure results for the all samples are described in figure 13 below based on their wt% of Al-powder.

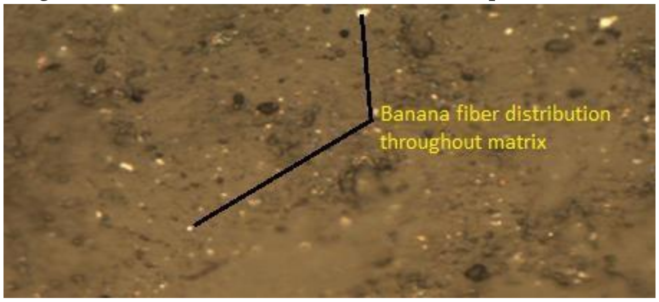

Fig 13: Microstructure of Sample A

Microstructure of sample A shows that banana fiber polymer matrix distribution was to some extent uniform. To obtain exact uniformity consider other orientation rather than non-woven, decreasing fiber chopped length, and even fabricating at micro and nano level may be best option. But, under this study it is suitable for automotive body application based on the mechanical and physical properties results.

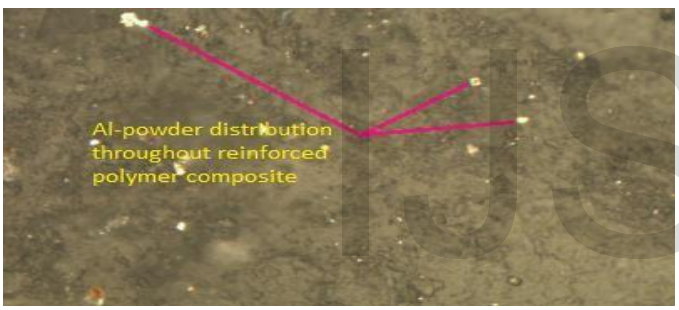

Fig 14: Microstructure of sample B

Al-powder filler was seen as it was distributed randomly throughout laminated composite. At Microstructure Al-powder filler was seen by white point boundary from banana fiber mixed by resin-hardener mixture.

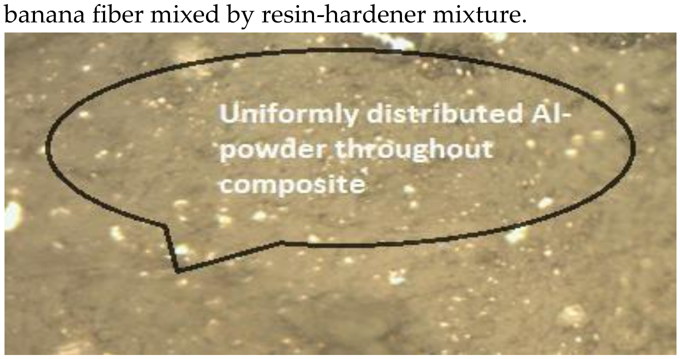

Fig 15: Microstructure of sample C

Al-powder distribution was seen at randomly mixed boundary to banana fiber polymeric matric composite. As Al-powder wt% increases the boundary of mixtures clearly shown. It has better Microstructure mixture.

Fig 16: Microstructure of Sample D

From result seen in sample D the distribution of Al-powder was not evenly distributed. It was somewhat collected to some boundary zone. This is due to metallic property of Al-powder that create oxidation with resin-hardener mixture. So, as Al-powder wt% exceed some point it was form oxidation before creating best composite based of weight fraction of fiber, resin-hardener mixture and Al-powder filler.

Shortly, beside on the light weight, low water absorption percentage, better tensile stress and good micro hardness the whole samples fabricated from banana fiber filled with Al-powder suitable for automotive body application when compared to other natural fibers those uses for the same purpose.

4. CONCLUSIONS

Banana fiber reinforced polymer composite filled with Al-powder exhibits excellent tensile strength with as Al-powder filler amount increases (by wt %). In this study, as wt% Al-powder filler by 10% shows maximum value of tensile strength. But beyond 10 wt% of Al-powder the tensile strength of the composite decreased. The maximum observed value of tensile strength was at sample C which has 33.07MPa. Generally, Al-powder filled composite have higher tensile strength than unfilled sample in this study. Based on the result obtained from this study sample D has the highest density value, while sample A has the lowest density. The density of sample D, C, B and A is 1.192, 1.151, 1.096, and 1.069 g/cm^3 respectively. Generally, all samples of banana fiber reinforced polymer composite fabricated for this study have lower density than pure Aluminium that has 2.7 g/cm^3. So, all samples are light weight and low in density.

Experimental result shows that micro hardiness decreases with Al-powder filler wt% increasing. Sample A has the highest micro hardiness value of 234.83MPa while sample D has the lowest micro hardiness value of 154.57MPa.

Results show that as Al-powder filler wt% increase to 15% water absorption percentage also decreases. Sample D has the lowest water absorption percentage of 2.79% which followed by sample C with value of 3.13%. Sample B has highest absorption value of 4.66% when compared to other fabricated samples. So, sample D is the optimal sample which followed by sample C for best water absorption percentage as the least number is more preferable.

Microstructure of each sample is observed by metallurgical (optical) microscope. Banana fiber reinforced polymer composite distribution of sample A shows randomly distribution of fiber through matrix. Sample B Al-powder distribution Microstructure seen in non-uniform fashion. Sample C has best Al-powder filler distribution throughout banana fiber reinforced polymer composite. But, in sample D Al-powder filler creates oxidation and form Aluminium oxidized major zone. Due to metallic property of Aluminium reaction will be happens with resin-hardener mixture before uniformly distributed throughout banana fiber reinforced polymer composite samples those fabricated. Addition of Al–powder more than 10 wt% forms oxidation before uniformly distributed throughout produced composite.

For justification since light weight, water absorption and strength are the crucial and critical factor in automotive industry to reduce fuel consumption and environmental pollution, banana fiber reinforced polymer composite filled with Aluminium powder filler is compatible to use in different interior part of vehicles. The maximum density of fabricated composite from banana fiber is obtained at 15 wt% Al-powder filled with 1.192 g/cm^3. This density is better when compared to 2.7g/cm^3 of Al-powder and 1.1 g/cm^3 of polyester resin.

Tensile strength of banana fiber reinforced polymer composite filled Al-powder filler fabricated under this study for sample A, B, C and D has an average tensile strength value of 23.87Mpa, 29.6MPa, 33.07MPa and 30.6MPa respectively. Micro-hardness and water absorption percentage of banana fiber reinforced polymer composite filled Al-powder is best when compared to synthetic fiber composite. When compared to other composite fabricated sample C has higher tensile strength, better Microstructure, moderate water absorption percentage and density. Overall optimal mechanical and physical properties obtained at sample C when compared to other samples fabricated in this study. Generally, based on mechanical and physical properties all samples are suitable for automotive body.

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