The potential of rising husk fiber/native sago starch reinforced biocomposite to automotive component

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Abstract. This work aims to examine the mechanical and thermal behavior of rising husk fiber/starch reinforced epoxy polymer composites. Experiments are carried out to study the effect of fiber and filler volume percentage on the mechanical and thermal behavior of epoxy-based polymer composites. The volume of fiber and filler is varied by 10%, 20%, 30%, 40%, and starch 5% and 10% and 1.5%, respectively. The specimens are fabricated by using hand layup technique. The specimens are expurgated according to ASTM standards. The effects of rising husk fiber and filler were examined under different thermal conditions. The mechanical results show that the addition of fiber increased the impact characters of epoxy resin, whereas the addition of starch shell filler increased the thermal conductivity of the composite. We found that the results show that the stacking sequences of rising Husk/starch fibers have a significant impact on thermal conductivity. Composites with the stacking sequence mode RH40 with 15% starch exhibit the highest thermal conductivity, 2.6 W/m·K, an enhancement of 472.72% over the thermal conductivity of the PC resin (0.55 W/m·K). It is significant.

1. Introduction

In this era, the use of composite materials has become ubiquitous in aerospace, automobiles, sports, and medical fields. But most of the commercially available composites are manufactured from the sources obtained from the fossil fuels that are depleting rapidly and are the major cause of environmental contamination. In addition to the pollution, the majority of these composites are nonbiodegradable and are ending up in the landfills. To deal with these sorts of problems effectively, there is an indispensable necessity for the development of sustainable bio-based composite materials, with the eco-friendlier end of life possibilities. Natural fiber-based bio-composites have many distinct advantages with huge possibilities in different application areas which will have a great impact on the practical applications [1].

Expected excellent properties of composite materials in the future such as low density, high specific strength and modulus, high rupture toughness, good thermal, shock resistance, high heat of ablation, chemical inertness, fiber reinforced carbon (C/C) composites have been successfully used in the fields of aviation, aerospace, automotive, nuclear power, medicine and so on. Composite materials which are used for energy conversion and storage have become more and more widely used in recent years for its advantage of good insulation, corrosion resistance, and lightweight, especially in that equipment such as electrolytic heat exchangers, satellite devices [1,2]. The thermal conductivity of
energy conversion and storage composite materials is an important indicator of the performance of the energy system and equipment such as heat exchangers. Enhancement of the thermal conductivity of composite materials is usually achieved by adding conductivity fillers thermally into the matrix materials. These thermal fillers can be divided into three categories: metal and ceramic particulate fillers [3–5], fiber fillers [6], and nanofillers [7], which have much higher thermal conductivity than the matrix materials. They mixing of different types of fillers are also used, such as glass fiber and multi-walled carbon nanotube [8], micron SiC and multiwalled carbon nanotube [9]. In recent years, numerous investigations have been carried out to modify the fiber/matrix interface to obtain high-performance C/C composites. As quasi-one-dimensional materials with a special structure, carbon nanofibers (CNFs) are widely used in C/C composites for interface modification [7,8]. The structure of fiber/matrix interface was deeply observed and analyzed. The mechanical properties and thermal conductivity of the modified composites were investigated in many studies indicate that the thermal conductivity of composite materials is influenced by the filler content and the thermal conductivity of the fillers. Kim [10] investigated the thermal conductivity of epoxy by adding AlN fillers, the results showed that the thermal conductivity of the AlN-filled composites would be about 2.5 times higher when the volume fraction increase from 50% to 60%, and it will be 7 to 8 times higher than the SiO2-filled composites when the volume fraction of AlN reaches 70%. Some other studies such as Tibbetts et al. [11] have found that the thermal conductivity of composite materials can reach as much as ten times higher than the polymer materials when the filler volume fraction and the thermal conductivity of composite materials are suitable enough. A much higher thermal conductivity of composite materials is reported in Norley’s research [12]. Jordan et al. [13] indicated that the shape of the fillers, the matrix materials and the morphology of the fillers have effects on the thermal conductivity of composite materials. The new regulations in the automotive industry is such as the. Corporate Average Fuel Economy (CAFE) standard, stress a new driving force for all the automakers to improve on fuel efficiency which has resulted in the reduction in weight of their vehicles. For this, the replacement of all the nonrenewable and high-density fillers such as talc, glass and carbon fibers by sustainable and lower density fillers such as natural fibers are getting more attention. Indeed, the effective use of bio-based fillers as sustainable and renewable alternatives for the fabrication of polymer composites has been receiving great importance in recent years due to the concerns about environmental and diminishing petroleum resource related issues. Natural fibers, wood flour, and cellulose, are some of such fillers which have been well explored, engineered and commercialized in different applications [14,15].

However, most of these have been used as reinforcement in commodity plastics such as polypropylene (PP), polyethylene (PE), polystyrene (PS) and polylactic acid (PLA). The use of these bio-based fillers in engineering plastics has been problematic because of their low thermal stability and hygroscopicity. Natural fibers begin to degrade around 180–200 °C and cannot be successfully incorporated into engineering plastics without thermal degradation. They easily absorb moisture from the surrounding environment and can be detrimental to moisture sensitive plastics like polyamide and PET during melt compounding at higher temperatures. Polyamide, with a processing temperature range of 250–290 °C, is one of the most commonly and widely used engineering plastic with various applications in automotive, electronics, construction and textile [16]. Therefore, research is being done on how to successfully incorporate natural fibers into polyamide without degrading it or resulting in composites with poor properties. In our previous work, this facile pretreatment was used to manufacture the binary cellulose/PLA composites. The goal of this research is to develop 100% bio-based and degradable ternary cellulose/PHBV/PLA composite materials via such facile fabrication. Pulp cellulose fibers were ball milled to access the filler with appropriate physicochemical properties in a solvent-free way. Then, the effects of the ball-milled cellulose particles on the morphology and mechanical properties of the resultant composite materials were investigated experimentally and statistically. According to to Sias [17], considers what determines whether a material will be a good
conductor or thermal insulator are the bonds in its atomic or molecular structure. Materials that are bad heat conductors have the outermost electrons of their atoms tightly connected.

Borges [15] explains that materials such as cotton, sugarcane bagasse, sisal, coconut fiber, and others can be used in natura as thermal insulation without needing treatment, as they have low thermal conductivity, and the use of these materials in the production of a composite can be economically and ecologically viable.

The study aims to develop and collection the potential of the material low of thermal conductivity can apply to engineering, obtained from the rise husk particle/Starch reinforced epoxy resin bio-composite can be used will act as thermal insulation for various the future applications as interior automotive and building, etc.

2. Material and Methods
2.1. Raw materials
Rise husk particles was supplied by rising milling on the West Sumatra and starch bought from the cake shop, then the rice husk is sifted to get a uniform fiber dimension, with fiber length 2 mm and density: 0.92 g/cm³. First of all, rise husk was maintained in NaOH solution for 8 h at room temperature to remove the impurities, followed by washing with distilled water until it reaches neutralization PH.

![Figure 1. Rise husk and starch](image1.png)

![Figure 2. Polyester resin](image2.png)
Figure 3. Thermal conductivity ASTM C177-92 apparatus

Keterangan:

1. Arduino Mega
2. Kabel jumper
3. Max6675
4. Termokople 1
5. Termokople 2
6. Termokople 3
7. Heater
8. Testing Tube
9. Isolation Room
10. Water Sensor
11. Relay
12. Resistor

Table 1. Mechanical characteristic polyester [9] [1]

| Characteristics          | ASTM | Unit   | Value   |
|--------------------------|------|--------|---------|
| Spesific gravity         | D 792| -      | 1,10-1,20 |
| Elongation               | D 3039| %     | 1,5     |
| Tensile strenght         | D 3039| N/m²  | 55.152  |
| Flexural strenght        | D 790 | N/m²  | 93,069  |
| Compressive strenght     | D 695 | N/m²  | 151.668 |
**Heat-deflection**

| Heat-deflection D 790 | N/m² | 41,364 |
|-----------------------|------|--------|

**Thermal Characteristics**

| Temperature | D648 | °C (°F) | 189 |
|-------------|------|---------|-----|

**Thermal Conductivity**

| ASTM C177-92 | W/moC | 0.487 |
|---------------|-------|-------|

**Thermal Resistance**

| ASTM C177-92 | °C/W  | 4.03  |
|---------------|-------|-------|

**Table 2. Material testing (rise husk fiber with epoxy resin nonstarch).**

| Sample | Resin Vol(%) | Rise Husk Vol (%) | Starch Vol (%) |
|--------|--------------|-------------------|---------------|
| RH    | 100          | 0                 | 0             |
| RH10  | 90           | 10                | 0             |
| RH20  | 80           | 20                | 0             |
| RH30  | 70           | 30                | 0             |
| RH40  | 60           | 40                | 0             |

**Table 3. Material testing (rise husk fiber with epoxy resin 5% vol starch).**

| Sample | Resin Vol(%) | Rise Husk Vol (%) | Starch Vol (%) |
|--------|--------------|-------------------|---------------|
| RH    | 100          | 0                 | 5             |
| RH10  | 90           | 10                | 5             |
| RH20  | 80           | 20                | 5             |
| RH30  | 70           | 30                | 5             |
| RH40  | 60           | 40                | 5             |

**Table 4. Material testing (rise husk fiber with epoxy resin 10% vol starch).**
2.2. Treatment of reinforcements
The rise husk particle reinforced epoxy resin were pre-treated in a hot oven to remove acquired moisture. Composite fabrication: A fixed volume of epoxy resin along with a variable volume percentage of the rise husk particle were used for composite making, dimension the composite material 40 mm length, 30 mm width, which varies from 3 mm to 5 mm. All composites were cured at room temperature for 48 h.

2.3. Specimen preparation
The designation and composition of the prepared rise husk fibre/starch reinforced epoxy resin are listed in Table 2 until Table 5. The rise husk/starch used for the tests were made by mixing an epoxy resin with increased hardening and fiber with material testing. The size of the fabricated material laminate is restricted 400 mm x 300 mm x 3 mm.

3. Results and discussion

3.1. Mechanical properties
Table 2. shows the tensile, flexural, impact, and hardness values of rising husk fiber/starch particle reinforced epoxy resin. Five identical specimens were used to measure average values in mechanical properties. The tensile results revealed that additions of woven mat rise husk natural fiber increased the tensile strength. Improved tensile strengths of 10%, 20%, 30%, 40%, with increased starch 5%, and 10% and 15%, were observed for composite designations RH, RH10, RH20, RH20, RH30, and RH40, respectively. This is because of the addition of starch improved load sharing in the epoxy matrix. The dispersed 5% until 15% w/wt starch shell particles filled the cap in the fiber and thus enhanced the load-sharing capability.
3.2 Mould preparation

For the sample preparation, the first and foremost step is the preparation of the mold which ensures the dimension of 400×300×30 mm the composite to be prepared. We have to prepare moulds for the preparation of 10% until 40 % rise husk and another 0% until 15% starch reinforced epoxy resin of the composite having 3mm and 5mm fiber length. A clean smooth surfaced wooden board is taken and washed thoroughly. The Steel plate (as shown in figure 5) was covered with a mold release sheet.

![Figure 4. Molds for making composite plates](image)

3.3. Measurement of Thermal conductivity

The thermal conductivity of the sample was measured by using Lee’s apparatus as shown in Figure 2. For the measurement of electrical conductivity of the sample, the instruments were arranged as shown in Figure 2. The sample was placed in between two copper plates in which one of the copper plated was fixed, and the other is fixed in such a way that the sample can be easily placed and remove. The adjustable terminal of the plate is directly connected with the negative terminal 12V battery, and thus the fixed foundation plate was a cathode. A digital multimeter was connected with the other end of the battery. By short-circuiting the circuit, the fixed resistance was calculated. Then the sample was placed between the fixed and adjustable foundation and sufficiently tightened by using the bolts.

The analysis was performed through the graphs that related the values of the coefficient of thermal conductivity $k$, and the temperature variation between the external and internal surface of the test sample. Before measuring the thermal conductivity, the samples were firstly dried in an oven at a temperature of 85 °C until a constant weight was obtained. The thermal conductivity was measured according to parallel and perpendicular direction with the compaction direction [12]; however, the results presented here are mean values of measurements taken on at least two different sides of the sample. ( face side and lateral side). The thermal conductivity value is calculated from the following equation 2.1.

At the non starch (0 %) or lower concentration of the particle, the thermal conductivity increases with the increase of heating time. The particle concentration due to the heavy air dragging force between the vibrations of air particles and increasing further due to increasing of the smoothness of the sample, for which as compared to the low-density thermal energy increases slightly because of the ion exchange characterization of the epoxy polymer chain and banana fibers.

Figure 5 shows the thermal conductivity of the composites filled with the rise husk and nonstarch fillers. The thermal conductivity increases as the heating time are increased at 80°C. The thermal conductivity of the RH30 composite was 0.57 W/m·K, an enhancement of 96.54% over the thermal conductivity of the PC resin (0.55 W/m·K).The thermal conductivity of composites is not changing with thermal conductivity of the PC resin. Figure 6 From this perspective, the higher thermal conductivity of the composites filled with RH 40 with 5% starch composite was 0.59 W/m·K an enhancement of 107.72% over the thermal conductivity of the PC resin (0.55 W/m·K). Figure 7 From
this perspective, the higher thermal conductivity of the composites filled with RH 40 with 10% starch composite was 0.71 W/m·K an enhancement of 129.21% over the thermal conductivity of the PC resin (0.55 W/m·K). Figure 8 From this perspective, the higher thermal conductivity of the composites filled with RH 40 with 15% starch composite was 2.6 W/m·K an enhancement of 472.72% over the thermal conductivity of the PC resin (0.55 W/m·K) can be expected. However, this unexpected result can be caused by the interfacial thermal resistance between the starch filler and the polymer resin, and the interfacial thermal resistance negatively affects the phonon transfer between the filler and the resin[16,17]. In particular, it is considered that the RH40 filler is smaller in size than the raw starch filler and, given the same content, form more interfaces with the resin within the composites.

Figure 5. Thermal conductivity with starch vol 0 (%)
4. Conclusion
The results show that the stacking sequences of rising Husk/starch fibers have a significant impact on thermal conductivity. Composites with the stacking sequence mode RH40 with 15 % starch exhibit the highest thermal conductivity 2.6 W/m·K an enhancement of 472.72% over the thermal conductivity of the PC resin (0.55 W/m·K) it is significant. It is subsequently shown that. It can be concluded that stacking sequences in rising husk/starch epoxy composite is an effective way to modify the thermal conductivity of composite materials in engineering products. Rise usk/starch fiber is, therefore, an excellent insulating material. Furthermore, it can be concluded that temperature is an effective influence on material structure. However, material structures cannot change when temperatures are lower than melting temperatures.
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5. References
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