A study on flexural and water absorption of surface modified rice husk flour/E-glass/polypropylene hybrid composite

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Abstract. This work is to study the effects of rice husk (RH)/E-Glass (EG)/polypropylene (PP) hybrid composites in terms of flexural and water absorption properties. The tests conducted are the flexural test and also the water absorption test using two types of water: distilled and sea water. The hybrid composites are prepared with various ratios of fibre weight fractions and the rice husk is treated using 2% Sodium Hydroxide (NaOH) to improve interaction and adhesion between the non-polar matrix and the polar lignocellulosic fibres. It was found that the content of rice husk/E-Glass fillers affected the structural integrity and flexural properties of hybrid composites. In addition, a higher ratio of rice husk contributes to higher water absorption in the hybrid composites.

1. Introduction
Common polymer matrices used in composites can be classified into thermoplastics, thermosets or elastomers. Polypropylene (PP) belongs to the group of thermoplastics, which is the synthetic polymer with many applications. Due to its high-volume and low-cost, PP is produced in large quantities and widely used in fabrication of automotive parts since 1959. As of now, most parts are produced using petroleum-based plastics but alternatives are needed to supplant the plastics materials while giving the suitable mechanical execution and ideally reducing the cost for the final item. With the increase in the environmental cognizance, ordinary fibres have growing interest to be used as reinforcing resources for fibre-strengthened composites due to their low cost, low density, renewability, biodegradability, and high particular stiffness and strength. Synthetic or natural fibres such as coconut coir, bamboo, banana, sugar cane, kenaf and palm oil are being used by many researchers [1-6]. Fabricating particle reinforced composites is much easier and with less cost than fabricating fibre reinforced thermoplastic composites. With polymeric matrices, the particles are easy to be added into the polymer melt in an internal mixture apparatus during polymer processing. Presence of particles can decrease the ductility and permeability of the matrix, and increase the modulus of the matrix. Filler is generally associated with a low cost material that is added into the formulation to decrease the cost of matrix materials [7].

Rice husk is an alternative natural fibre for production of composite and hybrid composites. In general, the fibres usage is also not thoroughly free from issues. A natural fibre, which is hydrophilic material, does not have good interaction with wide range polymers, corresponding to sago starch and thermoplastic [8]. Rice husk is a product from rice mills and it creates disposal and pollution issues. A few papers were published with discussions on the rice husk [7, 9-13]. Efficiency and performance of the composite materials rely on the properties of each material component and also their interface similarity. To make sure suitable interface interactions between them, their surface properties must be...
modified thoroughly. The essential ingredients of rice husk are ash, lignin and cellulose [10]. Figure 1 shows the microstructure picture of untreated rice husk.

Researches in rice husk fibre-strengthened composites have targeted the development of material properties through chemical response. Studies thus far have investigated several treatment agents that can modify rice husk surfaces to reinforce its efficiency. Chemical treatment of cellulosic materials usually changes both chemical and physical structures of the fibre through the reaction of OH groups on the cellulose fibres. There have been reports confirming that chemically-handled natural fibres are extra stable and can face up to a greater extent of heat compared to untreated fibres [1-6] during the course of thermal cycling. If the treatment improves the distribution and orientation of the fibres, then the fibre surface becomes more hydrophobic.

The objective of this work is to explore the effects of treated flour rice husk loading on flexural strength and water absorption behaviour of the RH/EG/PP hybrid composite. The hot press surface of the hybrid composite is also examined to study fibre-matrix interaction and distribution of fibre in the matrix.

2. Material
The materials utilized were "Polypropylene" (polymer) and rice husk (natural fibre) as a reinforcing of glass fibres (synthetic fibre).

2.1. Polypropylene
Polypropylene has been utilized as the matrix materials in the production of polymeric materials. The Polypropylene used in this study was of a "pellet" type, which was Polypropylene TITANPRO 6331 with melt stream rate at 230°C and thickness of 0.9g/cm$^3$.

2.2. Rice husk
Rice husk was obtained from the rice field in Kedah, Malaysia. The average granule size was 800 µm and the moisture content was 13 wt%.

2.3. E-Glass
The manufactured fibre in this study was E-Glass fibre (E2-4533 6000), which was supplied with the guide of DK composite. The primary ingredients of E-Glass fibre were 4.5 wt.% magnesium oxide, 8 wt.% boron oxide, 17 wt.% calcium oxide, 15 wt.% aluminum oxide and 54 wt.% silicon oxide. The E-Glass fibre has an elastic modulus of 72.5 GPa and a density of 2.59 gm/cc. The selected fibre glass size was cut in to 6 mm.

2.4. Formulation
The components of rice husk, E- Glass and polypropylene were separated into six compositions as shown in Table 1.

| Sample | RH (wt. %) | EG (wt. %) | PP (wt. %) |
|--------|------------|------------|------------|
| 1      | 0          | 0          | 100        |
| 2      | 0          | 60         | 40         |
| 3      | 60         | 0          | 40         |
| 4      | 30         | 30         | 40         |
| 5      | 15         | 45         | 40         |
| 6      | 45         | 15         | 40         |

Table 1: Composition ratio of rice husk (RH), E-Glass (EG) an Polypropylene (PP)

Figure 1. Untreated rice husk
2.5. Treatment of rice husk
The washed rice husk was boiled in water with temperature of 100°C for roughly 60 minutes. Figure 2 shows the treatment procedure of the boiled rice husks. The boiled rice husk was soaked for 120 minutes with 2% concentration of sodium hydroxide, and it was then dried under direct sunlight for 4320 minutes. Figure 3 depicts the microstructure of the boiled and the NaOH treated rice husks. The NaOH treated rice husk showed rougher surfaces than that of the boiled rice husk.

![Figure 2. The treatment process of rice husk](image)

![Figure 3. Microstructure of: (a) treated boiling rice husk, (b) NaOH treated rice husk](image)

3. Experiment
A thermal mixing method was implemented using HAAKE™ Rheomix Lab Mixers for the HAAKE™ PolyLab™ 600 OS System as the internal mixer at a temperature of 180°C and 480 seconds with a rotor speed of 50 rpm. By means of this approach, the mixture of substances was predicted to be better and more uniform before entering the crusher machine to produce an average particle measurement of 0.2 cm length x 0.2 cm wide. The last phase of the composite development in this study was the hot pressing (Figure 4). Hot pressing was completed at a temperature of 180°C for 600 seconds and the
blend was then cooled below the room temperature for 900 seconds. The resultants were plates with measurements of 20 cm length x 20 cm wide x 0.2 cm thick and they were arranged into the cutting pieces as required by ASTM D790 and D570 standard for testing.

3.1. Flexural testing

Three point bending flexural test was performed using the Shimadzu Universal Testing Machine in accordance to ASTM D790. Dimension of the samples was 6 cm length x 1.27 cm wide x 0.2 cm thick and they were tested at a 10 mm/ min of crosshead speed (for seven samples from each composition). The tests were completed in controlled environments with 50% of humidity at 25 ± 3 °C. Figure 5 shows the process while Equation 1 and Equation 2 were used in the solution method.

\[
\sigma_f = \frac{3PL}{2bd^2}
\]

where \(\sigma_f\) = stress at midpoint in outer fibres (MPa), \(P\) = load at a given factor on the burden deflection curve (N), \(L\) = support span (mm), \(b\) = width of experiment beam (mm) and \(d\) = depth of demonstrated beam (mm).

\[
E_B = \frac{L^2m}{3bd^3}
\]

where \(E_B\) = modulus of elasticity in bending (MPa), \(L\) = support span (mm), \(b\) = width of experiment beam (mm), \(d\) = depth of demonstrated beam (mm) and \(m\) = slope of the tangent to the initial straight-line portion of the load deflection curve (N/mm).

3.2. Water absorption testing

The water absorption test was done by ASTM standard D 570. It involved a whole immersion of the seven specimens in distilled and sea water at room temperature. Specimens with measurements 3 cm length x 1 cm wide x 0.2 cm thick were removed from the panel using a hand saw. All the specimens were dried in an oven at 50 °C for 720 minutes and then kept in desiccators. The water absorption test was done by weighing the specimens at regular intervals using a weighing scale. The percent moisture content/weight gain, \(M_i\) is calculated by Equation 3.

\[
M_i = \frac{W_i - W_b}{W_b} \times 100
\]

where \(M_i\) = weight gain in percentage, \(W_i\) = weight of the specimen and \(W_b\) = oven dry specimen weight or baseline weight.

3.3. Observation of Scanning Electron Microscope (SEM)

The microstructure of materials was obtained using the FEI/Philips XL-30 Field Emission ESEM that activated from 20 kV till 30 kV. The fractured specimens from flexural test were initially dried and
coated with the gold using (E-5100) Sputter Coater Polaron classification. Scattering condition of the RH/EG fibre and break type of the hybrid composites under the hot press processing were determined.

4. Results and discussion

4.1. Flexural test

As shown in Figure 6 and Figure 7, flexural strength and modulus were reduced by the accumulation of natural fillers. Addition of 60 wt. % rice husk fibre to 40 wt. % PP resulted in decrease of flexural strength and modulus. However, addition of fibre EG increases the flexural strength and modulus of the hybrid composite. PP 40 wt. %, EG 45 wt. % and RH 15 wt. % mixture was observed and the flexural strength and modulus with composition of EG were higher compared to other compositions. It is proven by the result where the 45 wt. % of rice husk shows a lower value in hybrid composition. According to Ismail et al. [12] and Yang et al. [13], this is because the incapability of the fibre to support the stresses transferred from the matrix polymer to reinforcement, and negative interfacial bonding caused partly areas between polymer and reinforcement, and thus generated a weak structure.

4.2. Water absorption analysis

Figure 8 and Figure 9 exhibit the percent of two types of water absorption. They show the trend of two distinct forms of distilled and sea water in composite material. In the beginning, all specimens linearly increased in moisture absorption and achieved their immersion state at the highest moisture. From Figure 8 and Figure 9, composites with greater rice husk filling had the greatest absorption percentage. It was reported that fillers such as chopped rice husk, kenaf and wood correspond to much greater absorption when the fibre loading is increased [11, 14-15]. The addition of the EG fibre decreased the percentage of distilled and sea water absorption. The less amount of rice husk cellulose interaction with NaOH will give a low OH content [16].

The hydrophilic nature of rice husk causes water absorption in hybrid composites. Generally, the natural fibre strengthened composites exhibit large water absorption due to the presence of micro-voids at the reinforcement/matrix interface [17]. The constant polypropylene content of 40 wt% in all formulations and the different water absorptions among all hybrid composites can be used to illustrate the role of RH/EG ratio. The hybrid composite shows a moderate water absorption, which is 10.8%, 9.3%, 8.2% for RH 45 wt% / EG 15 wt%, RH 30 wt% / EG 30 wt% and RH 15 wt% / EG 45 wt%, respectively for distilled water and 11.9%, 10.8%, 9.3% for RH 45 wt% / EG 15 wt%, RH 30 wt% / EG 30 wt% and RH 15 wt% / EG 45 wt%, respectively, for sea water. This shows that the hybrid compound of fibre with treated rice husk fibre will limit the absorption of moisture into the distilled and sea water.
Figure 8. Graph of water absorption for distilled water

Figure 9: Graph of water absorption for sea water

4.3. Morphology of cracked specimens

The scanning electron microscope (SEM) was used to analyse the surface morphology of hot press specimens. The bonds surrounded by the RH/EG/PP hybrid composite structures were recognized by using the surface morphology. It is further used to observe the variations in the composite after mixing accordingly in hybrid form. Figure 10, Figure 11 and Figure 12 show results of surface morphology. The scanning electron microscope photos in Figure 10 and Figure 11 show the treated rice husk 30 wt. % and 15 wt. %. The RH/EG/PP images prove that integration mixed easily and have useful bonding surrounded by them.

Figure 10. Mixture of 30 wt.% RH, 30 wt.% EG, 40 wt.% PP

Figure 11. Mixture of 15 wt.% RH, 45 wt.% EG, 40 wt.% PP

Figure 12. Mixture of 45 wt.% RH, 15 wt.% EG, 40 wt.% PP

5. Conclusion

In this study, it was found that the content of RH/EG filler affected the structural integrity, flexural strength and water absorption behaviours of composites. Based on the observation, increasing the amount of the rice husk in PP/EG resulted in a decrease in flexural values. The water absorption value of the RH/EG filled PP was measured and it was observed that 15 wt. % rice husk had less absorption for distilled and sea water. It is thought that the hot press effects of the RH/EG led to an increased rate in orientation of the polymer. Rice husk in minimum content was taken to be an alternative additive to the PP/EG. If a suitable hybrid composition could be added to rice husk/E-Glass and PP mixtures, the flexural strength and water absorption properties can possibly be increased.

Acknowledgments

The authors acknowledge Jabatan Pendidikan Politeknik for association with this study effort, and Department of Mechanical Engineering, Polytechnic Port Dickson and Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka for allowing consent to use the apparatus.
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