

Comparative studies of Titanium Dioxide and Zinc Oxide as a potential filler in Polypropylene reinforced rice husk composite

M Awang and W R Wan Mohd

School of Ocean Engineering, Universiti Malaysia Terengganu, 21300 Kuala Terengganu, Terengganu, Malaysia

E-mail: wroslinamohd@gmail.com

Abstract. Arising global environmental issues have triggered the search of new products and processes that are compatible with the environment while maintaining novel properties of materials. In this work, green composites containing rice husk (RH), polypropylene (PP), and incorporated with two different fillers namely titanium dioxide (TiO_2) and zinc oxide (ZnO) were prepared using an internal mixer and were injected into desired specimen by using an injection molding method. Mechanical properties of the composite were studied using Instron universal testing machine with load cell of 30kN capacity. Morphological of tensile fractured surface of composites was observed using scanning electron microscopy (SEM). The results show that the composites with the addition of TiO_2 gave an excellent mechanical properties than the composites filled with ZnO . Furthermore, morphological image of PP/RH/ TiO_2 also shows a good interaction occurred between polymer matrix and RH particles as compared to that of PP/RH/ ZnO .

1. Introduction

The novelty of materials is evaluated based on their mechanical characteristics such as tensile properties, compression properties, impact properties and flexural properties. These characteristics are essential to figure out material ability to withstand extreme and critical conditions resulted to their engineering performance [1].

Polymer composites reinforced natural fiber have attracted a broad attention of researchers in conjunction with arising concern towards environmental issues. This is due to a novel attribute of natural fiber which is renewable, biodegradable and sustainability. They also provide some excellent features such as light weight, low cost, eco-friendly and naturally degradable composites without eliminating its rigidity properties [2]. Rice husk is one of the natural fibers which comes from major agro-waste by-product with an abundance of sources and become a staple food in Malaysia. It is decomposed of cellulose 35 %, lignin 20%, hemicellulose 25% and ash 17% (silica 94%) by weight [3]. However, there are some shortcomings of this natural fiber where hydrophilic properties which belongs to lignocellulosic materials made their mechanical properties become lower than their synthetic counterpart. Another reason that led to low mechanical properties of the composites is poor interfacial bonding between the lignocellulosic material and the hydrophobic polymer matrix. Comprehensive studies has been made on polyolefin such as polypropylene and polyethylene and various natural reinforcing fillers, in conjunction with various chemicals that could affect the interface [4,5]. This drawback can be alleviated by the use of inorganic filler such as metal oxide which is TiO_2 , ZnO , CaCO_3 and others. The main purpose of utilization of inorganic



filler in polymer composite not only limited to cost reduction but it also to enhance the performance of mechanical properties such as rigidity, dimensional stability and toughness [6].

TiO₂ is an inexpensive and non-toxic semiconductor and extensively used to enhance the properties of polymers [7]. TiO₂ and ZnO have drawn broad attention in recent years due to their wide application especially in functional devices, pigments, cosmetics and ultraviolet (UV) absorber and antibacterial agent [7–14]. An incorporation of TiO₂ and ZnO into polymers does not only produce functional capabilities such as photostabilization and antibacterial agent but it also can enhance mechanical properties by providing a strong interfacial interaction between polymers matrix and filler [15]. The use of TiO₂ and ZnO with PP composite have been researched by a number of researchers in order to investigate the physical and mechanical properties [7,16-21]. To date, there is no research has been conducted relating to substitution of TiO₂ or ZnO filler into PP reinforced RH composites.

In this study reported herein, the influences of TiO₂ and ZnO on mechanical properties of PP reinforced RH composite is investigated. The morphological studies on fractured tensile surfaces were also carried out by using scanning electron microscopes.

2. Experimental details

2.1 Materials

Polypropylene was purchased from Lotte Chemical Titan in the form of pellets with a density of 0.900g/cm³ and melt flow index of 14g/min. RH was supplied by Bernas rice factory (Besut, Terengganu, Malaysia). TiO₂ and ZnO powder was obtained from Azfa Maju Trading, Terengganu.

2.2 Preparation of the composites and sample

RH was ground and sieved to produce mesh sizes less than 50µm. PP pellets, RH particles and TiO₂ filler were melt-mixed in a Brabender internal mixer. The content of TiO₂ filler was fixed to 3wt% and two levels of RH particle loading (10 and 40wt%) were used. For comparative purposes, ZnO content was also fixed to 3wt% and went through a similar processes. Composite samples were then fed into a Haake injection molding machine to produce specimens in the form of dumbbell shape.

2.3 Characterizations

2.3.1 Mechanical property. The mechanical property of the composites was investigated using an Instron Universal Testing Machine (Model 3366) with maximum load cell of 30kN capacities and cross head speed of 10mm/min.

2.3.2 Thermogravimetric analysis. The measurement of thermal stability was performed using a Thermo Balance SDTA 815E, in the temperature range 30°C to 900°C at heating rate of 10°C /min and under 30ml/min of argon flow.

2.3.3. Scanning electron microscopy. The morphology of the tensile fractured surface of the composite samples was performed using scanning electron microscope (JOEL model JSM 6360LA).

3 Results and Discussion

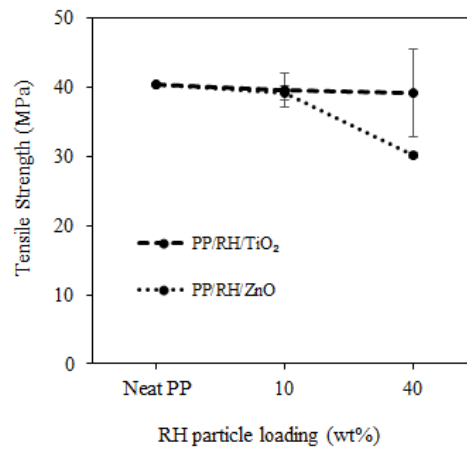


Figure 1. Tensile strength of neat PP, PP/RH/TiO₂ and PP/RH/ZnO

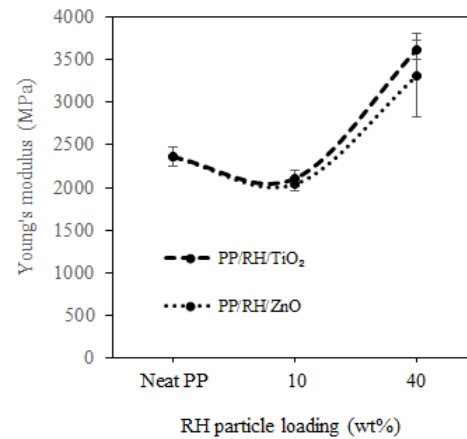


Figure 2. Young's modulus of neat PP, PP/RH/TiO₂ and PP/RH/ZnO

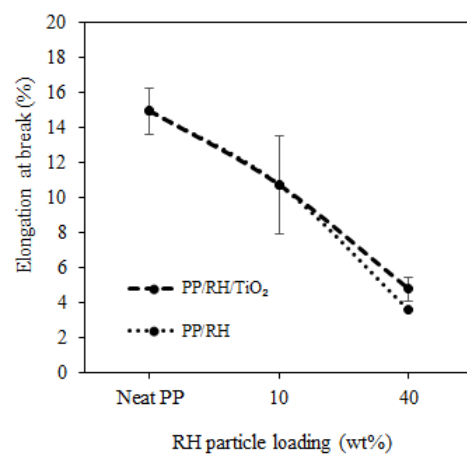


Figure 3. Elongation at break of neat PP, PP/RH/TiO₂ and PP/RH/ZnO

3.1 Mechanical properties

3.1.1 Tensile test. Figure 1 depicts the effect of RH particle loading on the tensile strength of PP/RH/TiO₂ and PP/RH/ZnO. It shows that the value of tensile strength of PP/RH/TiO₂-10wt% and PP/RH/TiO₂-40wt% minimally vary. The value of the tensile strength of these both composites are still in acceptable range and are very close to the value of ultimate tensile strength of neat PP which is 40MPa. It was highlighted that an addition of 3wt% TiO₂ in PP/RH composite has substantially increased tensile strength thus led to excellent mechanical properties. Esthappan et al. also mentioned that an addition of 3wt% of TiO₂, tenacity was significantly increased indicating the uniform distribution of TiO₂ in the PP fiber [22]. As compared to PP/RH/ZnO, by increasing RH particle loading to 40wt%, the tensile strength of the PP/RH/ZnO was slightly decreased. By adding 0.5 to 8wt% of ZnO, the values of tensile strength of PP fiber did not much improve because of poor interaction between filler and matrix [23].

3.1.2 Young's modulus. Overall, all RH particle loading series also indicate that the value of Young's modulus of PP/RH/TiO₂ was higher than PP/RH/ZnO shown in Figure 2. The trends of the plotted graph also increased with increasing of RH particle loading. This phenomenon occurred due to increasing of RH content in composites which directly contributed to an increase in composite stiffness. It was verified that stiffness of the PP/RH/TiO₂ composite increased from 2100MPa to more than 3600MPa while for PP/RH/ZnO composite increased from 2047MPa to more than 3300MPa. Luz et al. reported that natural lignocellulosic materials have higher elastic modulus attribute than PP [24]. A number of researchers also have been found that in the presence of high loading of natural fiber being as important factor in increasing composite's rigidity that causes the reduction of polymer chains mobility thus promote an occurrence of higher stiffness in the composite[25].

3.1.3 Elongation at break. Increasing RH particle loading resulted in an abrupt drop in elongation at break for PP/RH/TiO₂ and PP/RH/ZnO as compared to neat PP in (Figure 3). Generally, an incorporation of inorganic fillers into polymer composites enhances their mechanical properties such as tensile strength, elastic modulus but decreases impact strength and elongation at break [18, 26, 27]. Based on Figure 3, it also can be observed that elongation at break for PP/RH/TiO₂ was higher than PP/RH/ZnO. Altan et al. also found a similar result in PP composites whereby elongation at break of PP/TiO₂ was significantly increased as compared to ZnO reinforced composites especially for the filler loading over 1wt% [28].

3.2 SEM morphology

SEM micrographs of tensile fractured surfaces of neat PP, PP/RH/TiO₂-10wt% and PP/RH/ZnO-10wt% were shown in Figure 4 (a), (b) and (c) respectively. It can be observed that the RH particles were distributed uniformly in Figure 4 (b) unlike Figure 4 (c). It was also can be seen clearly, a poor interaction between polymer matrix and RH particles occurred in Figure 4 (c) as compared to Figure 4 (b). As RH particle loading was increased from 10 to 40wt% as shown in Figure 4(d) and Figure 4(e), there were some agglomerations in morphological structure in PP/RH/TiO₂-40wt%. Aydemir et al. mentioned that the agglomerations occurred due to increasing of filler loading [29]. An increasing RH particle loading also led to phenomenon of fiber pull out due to less interaction between polymer matrix and RH particle as clearly seen in Figure 4(e). Other works reported that when a free space exist between particles and polymer matrix, it is easy to have fiber pull out phenomenon during brittle fracture [30].

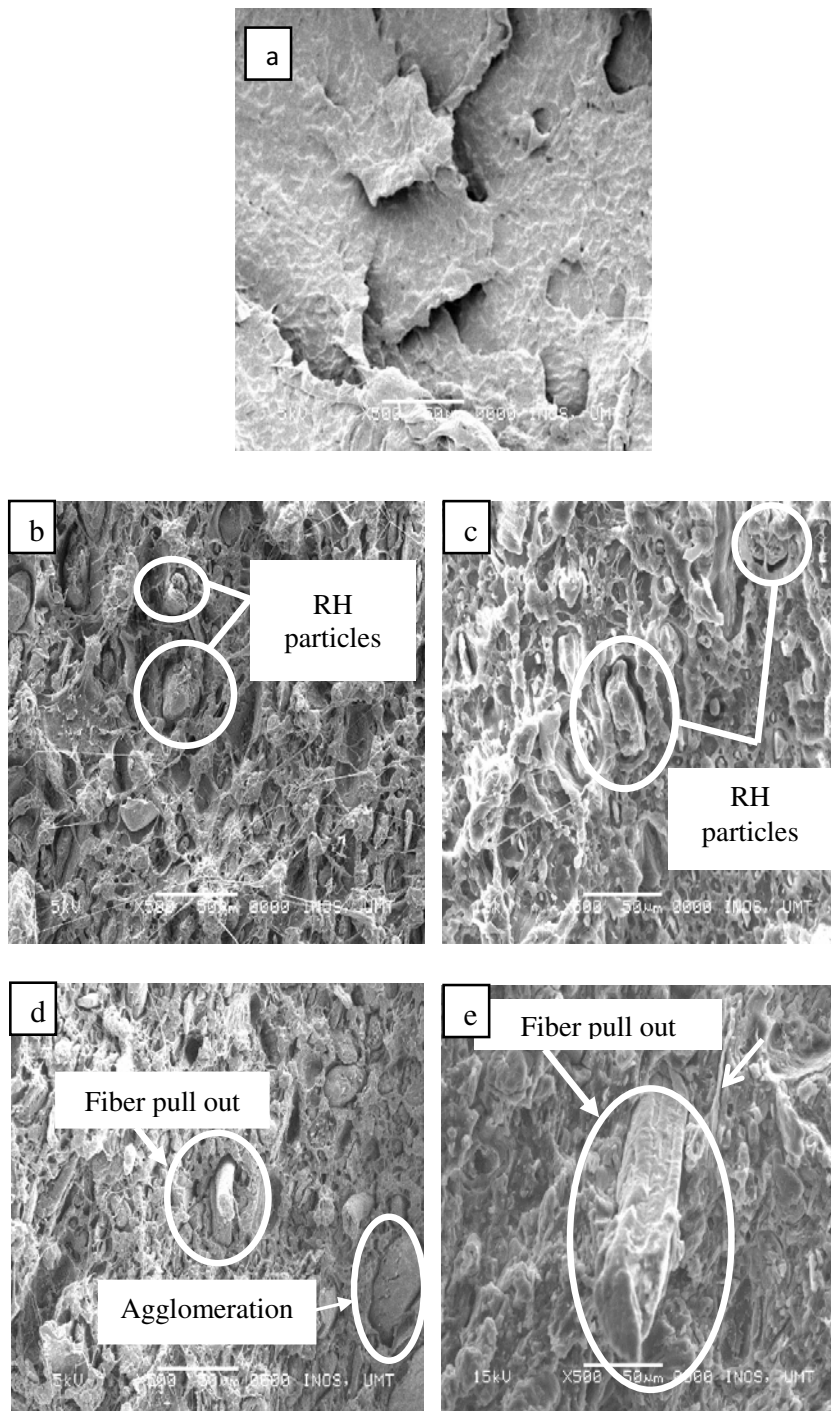


Figure 4. SEM micrographs of tensile fractured surface of (a) Neat PP (b) PP/RH/TiO₂-10wt% (c) PP/RH/ZnO-10wt% (d) PP/RH/TiO₂-40wt% (e) PP/RH/ZnO-40wt% composites

4 Conclusions

Inorganic fillers such as metal oxides behave different according to its physical, mechanical and chemical properties. In this work, two metal oxides namely TiO₂ and ZnO were used to improve properties of polypropylene filled rice husk composites. An addition of 3wt% of TiO₂ in PP/RH composites imparted an improvement to the mechanical properties. From tensile test, it shows that higher tensile strength and Young's modulus in PP/RH/TiO₂ than that of PP/RH/ZnO composites due to its hardness and stiff structure. Besides, the elongation at break of the PP/RH/TiO₂ was also higher than PP/RH/ZnO composites proven that the compatibility of PP/RH was better with TiO₂ compare than ZnO. From SEM morphology, PP/RH composites filled TiO₂ have a good interaction between polymer matrix and RH particles while fiber pull out appeared in some regions of PP/RH/ZnO led to the reduction of tensile properties of the PP/RH/ZnO composites.

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