Effect of Kenaf Fibre and Rice Husk Incorporation on Melt Flow and Mechanical Properties of Calcium Carbonate/Polypropylene Hybrid Composite

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Abstract

This research is conducted to determine the changes in melt flow and mechanical properties of kenaf and rice husk mix on hybrid composite filled with calcium carbonate, $CaCo_3$/PP hybrid matrix. Variable ratios of hybrid composite were incorporated using kenaf fibre (KF) and rice husk (RH) particulates which were mixed in different composition of 10:30, 15:25, 20:20, 25:15, 30:10, 35:5 with fixed 20% amount of $CaCO_3$. Compounded hybrid composite was prepared via twin screw compounder and tested for melt flow index (MFI), tensile and impact strength. When added with kenaf and rice husk, the composites exhibited lower MFI. All compounds showed MFI range from 2 to 3 gram/10 min. Highest MFI was observed with the highest ratio of rice husk to kenaf fibre (KF/RH 10:30) whilst the lowest MFI value was exhibited by the composite ratio of KF/RH 35:5 incorporated into the mix of $CaCo_3$/PP hybrid matrix. This implied that incorporation of kenaf fiber has resulted in higher resistance of the hybrid matrix thus causing the melting flow index to increase accordingly. Tensile strength, elongation at break and impact properties of hybrid composite have decreased due to the increasing content of the rice husk. For tensile properties, better stress transfers were exhibited by higher RH compared to KF which are shown from their higher tensile strength. Molecular interactions of $CaCo_3$/PP hybrid matrix can efficiently be provided by the stress transfer of RH after the addition of the filler into the hybrid. Meanwhile Young Modulus, E was also increased with addition of higher KF in $CaCo_3$/PP hybrid composite mainly due to greater rigidity imposed by the fibrous kenaf. Impact strength was improved with higher rice husk content KF/RH 10:30. The higher toughness of higher rice husk content for hybrid composite showed that rice husk provide better resistant to fracture embrittlement. The rice husk enhances the impact forces subjected to the hybrid composite due to high silica content in rice husk and its particulates.

Keywords: Hybrid Composites, Kenaf fibre, Rice husk, Calcium Carbonate, Melt Flow Index, Mechanical properties

1.0 Introduction

Natural fibre reinforced composites found to be an alternative solution to the ever depletion petroleum sources thus they receive greater attention and attraction from researchers. Lignocellulosic fibre offers various attractive benefits such as low cost of production, renewability, lightweight, eco-friendly, harmless to health, less abrasiveness and greater deformability thus provides advantages to the mechanical, physical and thermal properties of materials hybrid composite. The primary purpose of adding mineral filler into the hybrid composite is to reduce the cost of productions of the material compund. Moreover, the mineral filler mixed with lignocellulosic enhances the properties hybrid composite (Zuiderduin et al, 2003). Hybrid composites are made by combining two or more types of different fibres in a common matrix. Hybridisation of two types of short fibre in different length and diameter offer beneficial advantages over the use of fibre alone in a single polymer matrix (Mirbagheri et al, 2007).

These days, credits to the advancement of polymeric technology, there are numbers of plastic products that are environmental friendly. Due to the aim to apply green technology in order to secure a sustainable environment, natural fibre from plants has been widely used to reinforce fibre. In this research, kenaf fibre and rice husk particulates were used as natural fibres. Kenaf is used as fibrous reinforcement in hybrid composite due to its high aspect ratio. It also provides high stiffness and strength value to the filled hybrid polymer matrix. Rice husk is the outermost layer of a paddy grain and indeed the material can be utilise as a degradable filler of polymeric material which can minimise environmental pollution and at the same time appeared to be as a strong reinforcing filler (Yang et al, 2007). This research is primarily focuses on hybrid composite and aims to study the properties of kenaf, rice husk and $CaCo_3$ mixtures due to its potentially and economically low in production cost. In the future, more research and information are needed to provide more valuable results on the optimal strength performance of $CaCo_3$/PP composite.

2.0 Method

2.1 Material and sample preparation

Polypropylene (PP) was supplied by TITAN (M) Sdn. Bhd, injection moulded grade PM803. Both of kenaf fibre and rice husk particulate with 50 mesh were supplied from MARDI. Kenaf and rice husk were placed in an oven for drying at 100°C until it reached minimum 1-2 % moisture content. The 2000 mesh of $CaCo_3$ was obtained from ZANTAT Sdn. Bhd. Kenaf fibre and rice husk particulates were mixed with PP and $CaCo_3$. The incorporate compound was melt extruded using twin screw extruder at temperature profile 175°C to 185°C from feed zone to the die zone. The composition prepared as given in Table 1.

Table 1: List of important date

Sample	PP (%)	Kenaf (%)	Rice Husk (%)	$CaCo_3$ (%)
P0	40	-	-	20
P1	40	10	30	20
P2	40	15	25	20
P3	40	20	20	20
P4	40	25	15	20
P5	40	30	10	20
P6	40	35	5	20

2.2 Composite characterization

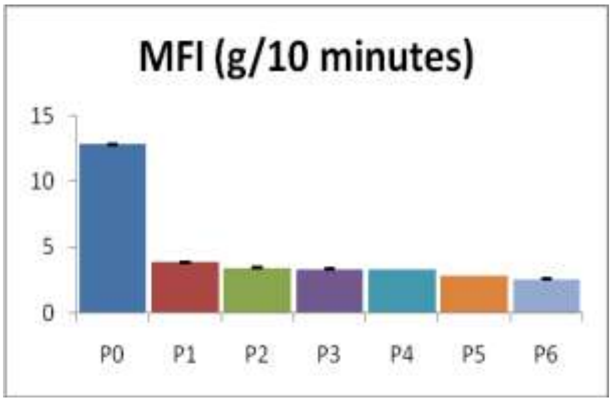
The tensile test was measured according to ASTM D638 specification. The test was carried out using Instron Machine at cross-head speed 5.0 mm/min. Impact properties were measured according to ASTM D256 using Izod Pendulum Impact Machine. The melt flow index of the samples was performed according to ASTM 1238 using Melt Flow Index machine in condition 190/2.16 (190°C and 2.16 kg).

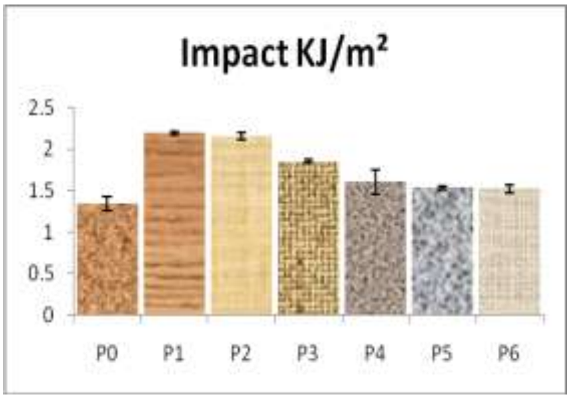
3.0 Result and Discussion

3.1 Melt flow index

Fig.1 shows the effects of kenaf and rice husk on MFI incorporate with $CaCo_3$/PP of hybrid composites. Melting flow index or MFI signifies the material flowing behaviour under fixed heat and pressure which also can provide indirect information on the material's molecular weight and viscosity (Islam et al, 2013). The result shows that the addition of higher kenaf fibre ratio to rice husk filler has decreased the hybrid MFI value. This is because kenaf fibre is composed of fibrous cellulose hence affecting the MFI value of the hybrid which was initially high (Tang and Liang, 2003). This is due to the poor flow between the fillers and the matrix during the melting process of the liquefied polymeric material. Based on the results obtained, it is confirmed that the hybrid's MFI decreased with additional of kenaf fibre. The resistance to flow is due to the filler existence which has formed agglomerate that promotes to the constituent inhomogeneity and cause uneven distribution of among the hybrid matrices and molecules. Mobility of chain had been affected by fillers which intrinsically have higher viscosity then PP matrix at specific temperature at 190°C.

Meanwhile, the particulate rice husk experienced easier flow compared to kenaf. The MFI for hybrid composite with 10% of kenaf and 30% of rice husk has the highest flow of 3.856 g/10 minutes compared to other filled $CaCo_3$/PP hybrid composite. Most difficult to flow was exhibited by 35% of kenaf fibre and 5% of particulate rice husk which is 2.557 g/10minutes. Result MFI for unfilled natural fibre Po is 12.0 g/10minutes. In general, melting flow of hybrid composite increased with kenaf fibre and rice husk filler loadings. MFI decrease significantly and decrease in resistance against the flow of hybrid composite were expected. Kenaf fibre impede flow more compared to rice husk; resistance to flow is imposed more by kenaf fibre as the fibre could attached at barrel wall of capillary and some fibres may have aligned and form bridges at central core of resin flow.





(a) (b)

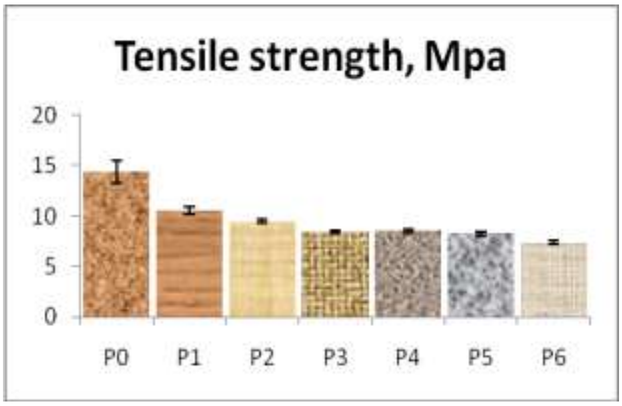
Fig. 1 (a) MFI (b) impact strength of the hybrid composites

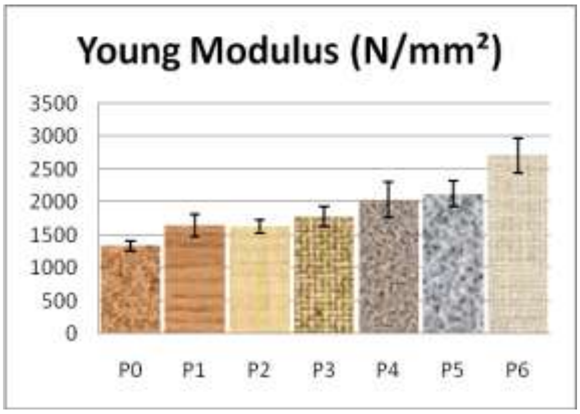
3.2 Impact test

In order to study the impact property of the hybrid material, Izod impact test, which specifies the amount of kinetic energy to initiate fracture and continue the fracture until the specific material is broken was done. The results obtained from Izod impact test is shown in Figure 1(b) where there is gradual decreased in impact strength with the increase in filler loading for kenaf/ $CaCo_3$/PP as the brittleness of the filler is higher than matrix resin. Hybrid composite higher with rice husk showed the resistance impact strength. This is due to the presence of rice husk particulate embedded in the matrix which can act to prevent the propagation of crack that generated during impact test. Therefore, kenaf does not contribute to the toughness of composite while rice husk has the better toughness filler which can resist impact in this hybrid system. Overall, kenaf and rice husk do give improvement in toughness with about 30% rice husk and lowest kenaf of 10%. It is discovered that the hybrid material exhibited 30% more toughness from P0 with PP and $CaCo_3$ only. It is also observed that kenaf does not give the toughening effect as good as rice husk which is due to the kenaf's fibrous structure or form of the filler. Particulate shape filler such as rice husk can prevent crack propagation compared to fibrous type filler.

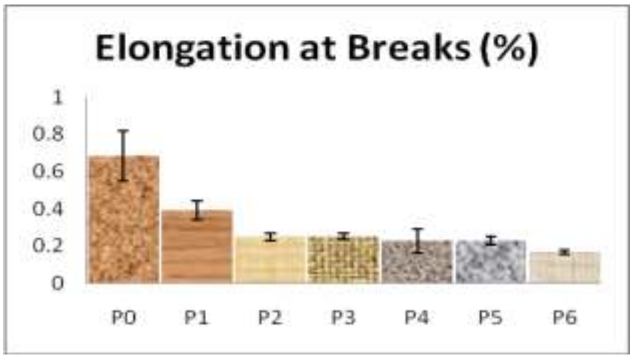
3.3 Tensile Strength

Figure 2 shows the tensile strength of filler hybrid composite with incorporate with $CaCo_3$/PP. The decreasing of hybrid composite tensile strength was observed. Incorporation of kenaf and rice husk has caused the decrease value of tensile strength in hybrid composite due to poor interfacial adhesion between fillers and resin.





(a) (b)



(c)

Figure 2: (a) Tensile Strength (b) Young's Modulus (c) Elongation at break of the hybrid composite

3.4 Young Modulus

The Young's modulus of incorporated $CaCo_3$/PP hybrid has increased due to the increased content of the kenaf fibre and decreased content of rice husk particulate as the Young's modulus increased the highest with the use of rice husk of 30% in the hybrid composite. Increasing filler loadings was due to inclusion of rigid filler in matrix which can cause the Young's modulus to increase. The maximum Young's modulus in 35% kenaf fibre and 5% of rice husk particulate was 2709 N/mm^2. While for the minimum value in 10% of kenaf fibre and 3% rice husk particulate was 1647 N/mm^2. It is learnt that the addition of kenaf fibre into $CaCo_3$/PP hybrid evidently increased Young's Modulus value of the hybrid.

Higher rigidity is shown by the highest modulus hybrid composite which has lowest rice husk content. Rice husk inherently has higher rigidity than kenaf and CaCo3. However, in this research, kenaf was found to have conferred more rigidity to the composite. This could be due to the effect of kenaf immobilisation of PP matrix chain. The whole of composite is affected as kenaf could form its own chain network and form caging effect and tangled and this cause the composite to exhibit high rigidity.

3.5 Elongation at break

Elongation at break, which is also known as strain of fracture is the proportion between altered length and initial length after breakage of a material specimen. Elongation at break test was done in order to understand the capability if the hybrid to withstand changes without crack formation during its future potential application. The effect of kenaf and rice husk incorporate with $CaCo_3$/PP on elongation at break in hybrid composite is as shown in Figure 2(c). The graph showed hybrid composite which decline in elongation at break. A similar observation has been reported by several research (Zuhaira et al, 2013; Premalal et al, 2003). The elongation at break of hybrid composite was drastically dropped once the kenaf fibre was added more than rice husk particulate to $CaCo_3$/PP. In addition, stress transfer from matrix to the filler phase can be improved by better dispersion and adhesion between filler and matrix. Flexibility of chain is reduced with higher kenaf as kenaf may impede with the immobility of PP chain unit and affect the hybrid composite system.

4.0 Conclusion

The application of plastic material in today's lives is almost undeniably important and significant. Plastic materials not only been used as packaging and household items, it is also specifically an important component of agricultural tools and mulching system, vehicles manufacturing, medical and hospital appliances. Though the material is substantially central in human lives, it is known to be as non-degradable due to its stability in nature. Degradation of plastic polymer products has been proven to take hundreds of years and prominently, the plastic wastes are ended up in urban drainage systems and landfills which contributed to the environmental pollution. Since its application cannot be stopped, or literally impossible; it is important for researcher to come with useful solution to overcome this issue.

With the advancement of polymer technology today, thanks to the progressive research by the researchers, it is discovered that natural fibre such as kenaf and rice husk can be used, if not overall, partially in the aim of producing a more environmentally friendly polymeric materials. Though, it is crucial to understand the character of the newly improved plastic polymer products so as to provide useful information for industrial key role in applying the technology. In conclusion, the addition of kenaf fibre and reduced composition of rice husk particulate in $CaCo_3$ /PP hybrid composite tends to decrease the MFI, tensile strength and elongation at break due to the different of compatibility between the hydrophilic filler and the hydrophobic polymer. These cause poor interfacial adhesion and dispersion of the filler and matrix polymer. Melt flow is affected by the high viscosity filler presence. In this hybrid composite system, impact strength decreased due to the increased content of kenaf and the decreased content of rice husk particulate in the experiment.

5.0 Acknowldgement

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