

Fabrication and Properties of Polypropylene and Kenaf Fiber Composite

Z Mustaffa¹, S Ragnathan¹, N S Othman¹, A A Ghani², W A Mustafa², A M Farhan¹, I Zunaidi³, Z M Razlan³, W K Wan³ and Shahrman A B³

¹ School of Environmental Engineering, Kompleks Pusat Pengajian Jejawi, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia

² Faculty of Engineering Technology, Kampus Sungai Chuchuh, Universiti Malaysia Perlis, 02100 Padang Besar, Perlis, Malaysia

³School of Mechatronic, Universiti Malaysia Perlis, 02600, Arau Perlis.

Email: mustaffazainal@gmail.com

Abstract. The effect polypropylene maleic anhydride (PPMAH) as a compatibilizer in mixing of polypropylene (PP) with kenaf fiber (KP) has been studied. Seven (7) different PP/KF composites ratio (100/0, 95/5, 90/10, 85/15, 80/20, 75/25 and 70/30) where compatibilizer use for PP/KF composite with fixed 3 wt% of maleic anhydride grafted polypropylene were carried out. In this project, all compound preparation was done by using a heated two-roll mill at a temperature of 180 °C for 7 minutes total of the mixing process. Then, the mixture was moulded by using a hot press machine at a temperature of 180 °C for a total 12 minutes to form 1 mm sheet and then cut into dumbbell shape. This sample was tested for mechanical properties include tensile strength, young modulus and elongation at break and morphology of the fracture surface of PP/KF composites. The result show PP/KF composite with compatibilizer has a higher tensile strength and young modulus compare to uncompatibilizer PP/KF composite. The adhesion between fiber and matrix has improved with addition of PPMAH compatibilizer. It make the PP/KF composite increase the stiffness and tensile strength. The scanning electron microscopy (SEM) study of tensile fracture surfaces of the PP/KF composites also indicates improved adhesion of kenaf fiber with polypropylene matrix with the presence of PPMAH compatibilizer.

1. Introduction

In past few years, many studies have been carried out on uses of natural fiber for polymer composites which are develop rapidly to meet varied end use such as transportation, economical building and other construction material [1,2]. It is because there was an abundance of natural fiber that can substitute with synthetic fiber such as glass and carbon because of synthetic material generally expensive, not environmentally friendly and not renewable [3,4].

Nowadays, kenaf research was more focused on the production of biofuel [5]. Many studies have been carried out which focusing on fabricating lighter and tougher PP/KF composites. The PP/KF



composite also having potential in order to improve fuel consumption for automotive part [6]. The beginning of kenaf history in Malaysia beginning in 1999 where it was initiated by the National Economic Action Council (NEAC) which formed a committee to identify the potential of expanding kenaf in Malaysia [7]. The most important thing to be a concern in the research of kenaf was to evaluate kenaf adaptation with climate in Malaysia [8]. As the commercial utilization of kenaf keeps on differentiating from its chronicled part to its various application like paper product, materials for building, and food for livestock [9]. Besides that, reinforced of natural fiber with polymer of PP/KF composite have concern as concern as innovative materials in several applications, however their potentiality is limited for certain industries [10].

Even though most of the natural fiber suitable to replace synthetic fiber, most of them are hydrophilic in nature which absorbs water and causes problems in between fiber and matrix [11]. So it will need some modification to gain better properties of PP/KF composite. In order to overcome the incompatibility between natural fiber and a hydrophobic polymer, the chemical modification was carried out to surmount the problem. The incompatibility may cause of polypropylene is non-polar and hydrophobic while lignocellulosic fiber material is polar due to the hydroxyl groups in the cellulose which will results in poor adhesion [12]. Maleic anhydride-grafted polypropylene (PPMAH) compatibilizer use to improve the interfacial adhesion between fiber and non-polar polymer [13–15]. In general, by using the plantation waste, it can decrease petroleum-based fuels products. So, kenaf has gain attention nowadays to use in the production of natural fiber PP/KF composite which is a combination of kenaf as fiber and polymer that is polypropylene as a matrix.

The main objectives of this research were to fabricate a PP/KF composite to evaluate the tensile and morphological properties of polypropylene and kenaf fiber PP/KF composite as well to study the maleic anhydride-grafted polypropylene effect of the polypropylene and kenaf PP/KF composite.

2. Material and Methods

Polypropylene (PP) Grade 6331 was provided by Titan Pro Polymers (M) Sdn Bhd Johor with a melt flow index of 14 g/10 min at 230 °C and a density of 0.9 g/cm³. Kenaf fiber (KF) is collected from the Malaysia National Tobacco Board. The KF were grinded into powder and sieved at a particle size of 150 µm. Then it was dried at 85 °C for 24 hours in the oven to remove the water content [16]. Polypropylene grafted maleic anhydride (PPMAH) was obtained by Sigma Aldrich Chemical with a melt flow index of 11.5 g / 10 min. 3 wt% of PPMAH was used as compatibilizer in this formulation.

Material	Function	Supplier
Polypropylene (PP)	Matrix	Titan PP(M) Sdn Bhd
Kenaf Fiber (KF)	Fiber	Lembaga Kenaf dan tembakau
Maleic Anhydride-grafted polypropylene (PPMAH)	Compatibilizer	Sigma Aldrich Chemical

2.1. Sample Preparation PP/KF Composite.

The melt mixing process at temperature 180 °C with rotor speed 15 rpm using a The heated two roll mill machine was used to prepared PP/KF composites. PP was melting followed by PPMAH and melted for 4 min. Then, KF was added continued for another 3 min and the compound was taken out. The total time for mixing was 7 min. The compound was prepared into 1 mm sheets using compression moulding. The hot-press machine was preheating at temperature 180 °C for 7 minute, compressing for 3 minute and cooling down the sample composite for 2 minute. The Wallace die cutter model S6/1/6.A. was used to cut composites into dumbbell shapes.

Table 1. The formulation for PP/KF composite with PPMAH as a compatibilizer in weight percentage.

Material	PP/KF composites composition (wt%)						
PP	100	95	90	85	80	75	70
KF	0	5	10	15	20	25	30
PPMAH	3	3	3	3	3	3	3

2.2. Tensile Properties

Tensile properties test followed ASTM 638 Standard Test Method to determine the tensile strength, Young's Modulus and elongation at break. Tensile tests were conducted using using an Instron Universal Testing Machine 5569 on the PP/KF composite samples. Before that, the thickness and width of each dumbbell specimens were recorded by using Vernier Calliper. Then all dumbbell specimens were tested with a 50 mm initial jaw and crosshead speed of 5 mm/min.

2.3. Scanning Electron Microscopy (SEM)

SEM is a scientific instrument, which utilizes a focused beam of electrons to inspect objects with much higher magnification and resolution. Platinum powder used to coated sample by using an auto fine coater model JFC-1600 from Japan to avoid electrostatic poor image resolution and charging during the testing. The morphological studied analyzed the tensile fracture surface of PP/KF composite. The observed samples were taken from the 1 mm dumbbell fracture surface samples from the tensile test. In this analysis, the magnification used was x200 magnifications.

3. Result and discussion

3.1. Tensile Properties

Figure 1 shows the tensile strength and Young's module of PP/KF composite uncompatibilizer and with PPMAH compatibilizer. The tensile strength was decreased with increasing of KF loading. This is maybe caused by the inability of fiber to support stress and distribute it to polymer [12]. On the other hand, the tensile strength of PPMAH compatibilizer PP/KF composite showed higher tensile strength compared to the uncompatibilizer PP/KF composite. The improvement by 3.98 – 18.50 % compared uncompatibilize composites. The presence of PPMAH in the PP/KF composite have better bonding between KF fiber and PP matrix [17,18].

Meanwhile, the Young's Modulus was increased with increasing of KF loading. This is may be due to the addition of fiber into the matrix has increased the stiffness of the PP/KF composite [19]. Furthermore can be seen Young's modulus of PP/KF composite is higher compared to uncompatibilizer PP/KF composite. It due to the replacement of a polymer matrix with smaller fiber particle, which improves the modulus of PP/KF composites [20,21]. The increase in modulus was also factor that deformation and matrix mobilization were limited by present of fiber particle that form mechanical barriers [22].

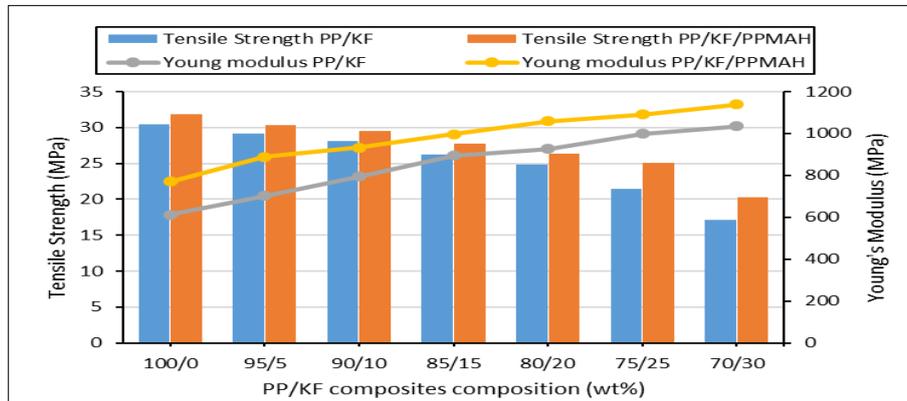


Figure 1: Tensile strength and Young's module of PP/KF composite uncompatibilizer and with PPMAH compatibilizer.

Figure 2 shows elongation at break, E_b of PP/KF composite uncompatibilizer and with PPMAH compatibilizer. It can be seen that uncompatibilize rPP/KF composite show a higher value of elongation compared to the compatibilizer PP/KF composite and this is maybe due to compatibilizer itself where the presence of hydroxyl group of PPMAH that improved the interfacial adhesion between polypropylene and kenaf which resulting the decreasing in elongation at break [23]. In addition, it can be seen that with increasing of fiber show the decreasing of elongation at break and as explain before, this could be due to the crack transmit through lack of interfacial region and caused the PP/KF composite to become brittle as well resulting low value of elongation [24]. The elongation at break decreased with a higher fiber loading cause the increased stiffness of the PP/KF composite.

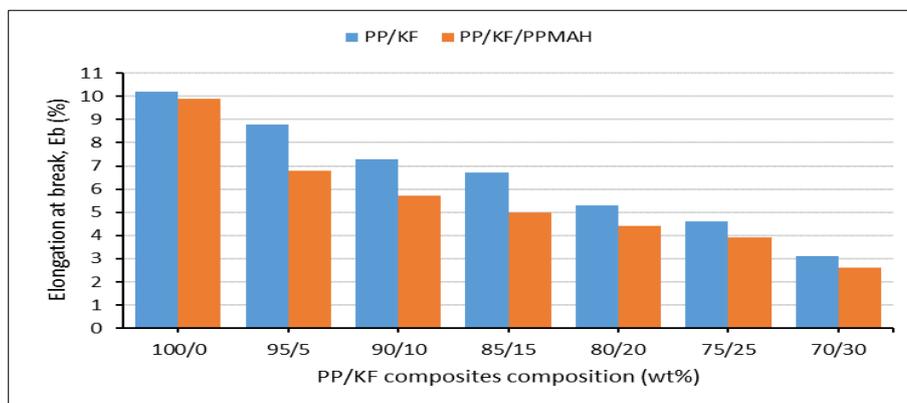


Figure 2: Elongation at break, E_b of PP/KF composite uncompatibilizer and with PPMAH compatibilizer

3.2 Morphological Properties

Figure 3 (a-b) shows SEM micrographs of the fractured surface morphology of PP/KF composite with KF loading of 70/30 wt% (a) uncompatibilizer (b) compatibilizer PP/KF/PPMAH composite. Based on Figure 3 (a) the detachment site of KF can clearly see. This due to PP matrix and KF have poor adhesion between them. Furthermore, the hole is observed in uncompatibilize composite. This because of poor interfacial adhesion between non-polar polymer and fiber [13].

Figure 3 (b) shows a better attachment of kenaf fiber on the PP/KF/PPMAH composites as the fiber has been encapsulated by the matrix. It shows improvement of attachment between kenaf fiber and matrix by using a PPMAH compatibilizer. This was proven that the compatibilizer was effective in improving the mechanical and morphological properties for the PP/KF composite. The less pull out fiber from the matrix and the fiber to the presence of compatibilizer PPMAH that improve the bonding of fiber in composite [25].

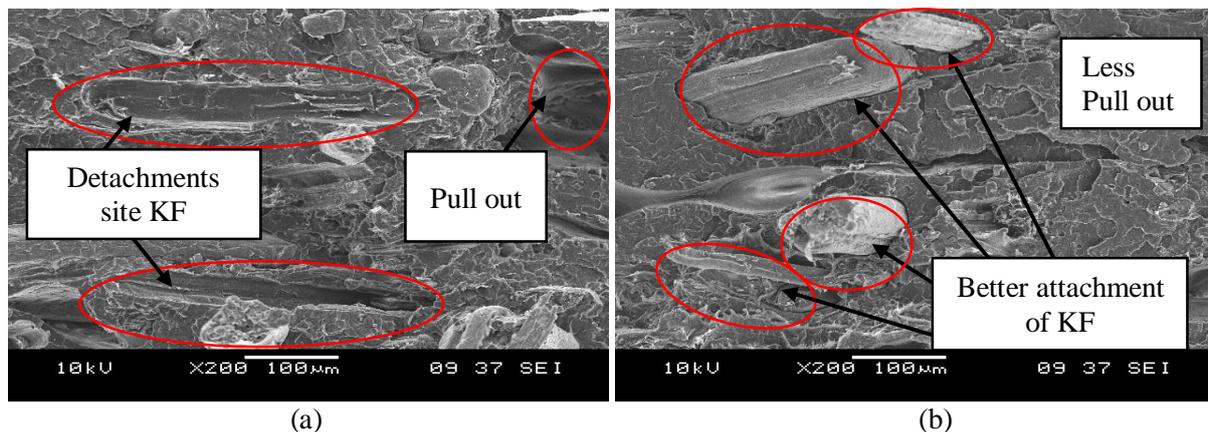


Figure 3: SEM micrographs of the fractured surface morphology of PP/KF composite with KF loading of 70/30 wt% (a) Uncompatibilizer (b) compatibilizer PP/KF/PPMAH composite.

4. Conclusion

In conclusion, PPMAH composites show an improvement in tensile strength by 3.98 – 18.50 % and Young's Modulus by 9.32 – 26.79 % compared to uncompatibilizer composites. Meanwhile, the elongation at break, E_b decrease by 2.94 – 25.37 %. Besides that, morphology properties for PPMAH composite show good interfacial adhesion and less pull out of kenaf fiber.

Reference

- [1] Sanjay M R, Arpitha G R, Naik L L, Gopalakrishna K and Yogesha B 2016 Applications of Natural Fibers and Its Composites: An Overview *Nat. Resour.* **07** 108–14
- [2] Mustafa W A, Saidi S A, Zainal M and Santiagoo R 2018 A Proposed Compatibilizer Materials on Banana Skin Powder (BSP) Composites Using Different Temperature *J. Adv. Res. Fluid Mech. Therm. Sci.* **43** 121–7
- [3] Thiruchitrambalam M, Athijayamani A, Sathiyamurthy S and Syed Abu Thaheer A 2010 A review on the natural fiber-reinforced polymer composites for the development of roselle fiber-reinforced polyester composite *J. Nat. Fibers* **7** 307–23
- [4] Mustafa W A, Saidi S A, Zainal M and Santiagoo R 2018 Experimental Study of Composites Material Based on Thermal Analysis *J. Adv. Res. Fluid Mech. Therm. Sci.* **43** 37–44
- [5] Saba N, Jawaid M, Hakeem K R, Paridah M T, Khalina A and Alothman O Y 2015 Potential of bioenergy production from industrial kenaf (*Hibiscus cannabinus* L.) based on Malaysian perspective *Renew. Sustain. Energy Rev.* **42** 446–59
- [6] Anuar H, Hassan N A and Mohd Fauzey F 2011 Compatibilized PP/EPDM-Kenaf Fibre Composite Using Melt Blending Method *Adv. Mater. Res.* **264–265** 743–7
- [7] Mohd H A B, Arifin A, Nasima J, Hazandy A H and Khalil A 2014 Journey of kenaf in Malaysia: A Review *Sci. Res. Essays* **9** 458–70
- [8] H'ng P S, Khor B N, Tadashi N, Aini A S N and Paridah M T 2009 Anatomical Structure and Fiber Morphology of New Kenaf Varieties *Asian J. Sci. Res.* **2** 161–6
- [9] Webber III C L, Bhardwaj H L and Bledsoe V K 2002 Kenaf production: fiber, feed, and seed *Trends in new crops and new uses* ed J Janick and A Whipkey (Alexandria) pp 327–339

- [10] Babaei I, Madanipour M, Farsi M and Farajpoor A 2014 Physical and mechanical properties of foamed HDPE/wheat straw flour/nanoclay hybrid composite *Compos. Part B Eng.* **56** 163–70
- [11] Zainal M, Santiagoo R, Ayob A and Mustaffa W A 2017 Mechanical properties and chemical reaction of 3-aminopropyltriethoxysilane of polypropylene, recycle acrylonitrile butadiene rubber and sugarcane bagasse composites *Int. J. Microstruct. Mater. Prop.* **12** 55
- [12] Santiagoo R, Ismail H and Hussin K 2012 Effects of Acetic Anhydride on the Properties of Polypropylene(PP)/Recycled Acrylonitrile Butadiene(NBRr)/Rice Husk Powder(RHP) Composites *Polym. Plast. Technol. Eng.* **51** 1505–12
- [13] Yang H S, Wolcott M P, Kim H S, Kim S and Kim H J 2007 Effect of different compatibilizing agents on the mechanical properties of lignocellulosic material filled polyethylene bio-composites *Compos. Struct.* **79** 369–75
- [14] Rangunathan S, Mustaffa Z, Kamarudin H, Sam S T and Ismail H 2017 The effect of polypropylene maleic anhydride on polypropylene/(recycled acrylonitrile butadiene rubber)/(sugarcane bagasse) composite *J. Vinyl Addit. Technol.* **23** 228–233
- [15] Affandi R D, Rangunathan S, Ismail H and Sam S T 2018 A study on mechanical and thermal properties of polypropylene/recycled acrylonitrile butadiene rubber/palm kernel shell composites with maleic anhydride grafted polypropylene as compatibilizer *J. Vinyl Addit. Technol.* **24** E125–32
- [16] Seng O H and Teik T S 2006 Drying of Kenaf in a Flat Bed Box Dryer for Animal Feed *J. - Inst. Eng.* **67** 17–21
- [17] Kim H S, Lee B H, Choi S W, Kim S and Kim H J 2007 The effect of types of maleic anhydride-grafted polypropylene (MAPP) on the interfacial adhesion properties of bio-flour-filled polypropylene composites *Compos. Part A Appl. Sci. Manuf.* **38** 1473–82
- [18] Santiagoo R, Affandi R D, Noraishah S, Ismail H and Hussin K 2016 The compatibilizing effect of polypropylene maleic anhydride (PPMAH) on polypropylene (PP)/acrylonitrile butadiene rubber (NBR)/palm kernel shell (PKS) composites *ARN J. Eng. Appl. Sci.* **11** 1666–72
- [19] Amri F, Husseinsyah S and Hussin K 2013 Effect of sodium dodecyl sulfate on mechanical and thermal properties of polypropylene/chitosan composites *J. Thermoplast. Compos. Mater.* **26** 878–92
- [20] Fu S Y, Feng X Q, Lauke B and Mai Y W 2008 Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate-polymer composites *Compos. Part B Eng.* **39** 933–61
- [21] Othman N S, Santiagoo R, Abdillahi K M and Ismail H 2017 Effect of polypropylene maleic anhydride (PPMAH) on mechanical and morphological properties of polypropylene (PP)/recycled acrylonitrile butadiene rubber (NBRr)/empty fruit bunch (EFB) composites *Proceeding of the 3rd International Conference of Global Network for Innovative Technology 2016 (3rd IGNITE-2016)* vol 1865 pp 1–5
- [22] Leong Y W, Abu Bakar M B, Mohd Ishak Z A and Ariffin A 2004 Characterization of talc/calcium carbonate filled polypropylene hybrid composites weathered in a natural environment *Polym. Degrad. Stab.* **83** 411–22
- [23] Wang N, Zhang J, Fang Q and Hui D 2013 Influence of mesoporous fillers with PP-g-MA on flammability and tensile behavior of polypropylene composites *Compos. Part B Eng.* **44** 467–71
- [24] Rangunathan S, Nurul S O, Abdillahi K M and Ismail H 2016 Effect of Maleic Anhydride-Grafted Polypropylene on Polypropylene/Recycled Acrylonitrile Butadiene Rubber/Empty Fruit Bunch Composite *J. Vinyl Addit. Technol.* **On Press**
- [25] Zainal M, Aihsan M Z, Mustafa W A and Santiagoo R 2018 Experimental Study on Thermal and Tensile Properties on Polypropylene Maleic Anhydride as a Compatibilizer in Polypropylene / Sugarcane Bagasse Composite *J. Adv. Res. Fluid Mech. Therm. Sci.* **43** 141–8