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Effect of Alkali Treatment and pMDI Isocyanate Additive on Tensile Properties of Kenaf Fiber Reinforced Thermoplastic Polyurethane Composite

Y. A. El-Shekeil [1+,] , S. M. Sapuan [1], K. Abdan [2] and E.S. Zainudin[3]

[1] Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia.

[2] Department of Biological and Agricultural Engineering, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia.

[3] Laboratory of Bio-Composite Technology, Institute of Tropical Forestry and Forest Products, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia.

Abstract. In this research, composite of themoplastic polyurethane (TPU) reinforced with short Kenaf (*Hibiscus Cannabinus L.*) fiber (KF) were prepared with different treatments, namely; TPU/KF with fiber pretreated by 2% concentration of sodium hydroxide NaOH, TPU/KF with additive of polymeric Methylene Diphenyl Diisocyanate pMDI 4% by weight and TPU/KF with the combination of both 2% NaOH and 4% pMDI additive. Effect of these treatments on mechanical properties (i.e. tensile, flexural and impact) was studied. Mean value was taken for each sample according to ASTM standards. Tensile strength has shown a decreasing trend. Tensile modulus was best for NaOH treated composite. Tensile strain was best for (2% NaOH+4% pMDI) treated composite. Flexural strength and modulus were best for untreated composite. Impact strength was best for (2% NaOH+4% pMDI) treated composite.

Keywords: Natural fiber composites, thermoplastic polyurethane, kenaf fibers, NaOH, pMDI.

1. Introduction

Day after day natural fiber reinforced polymers are grapping more attention due to benefits such as less abrasiveness to equipment, renewability, biodegradability and reduction in weight and cost. Lack of compatibility is one of the problems facing natural fiber polymer composites. Hydrophobic nature of most polymers used in this field, versus, hydrophilicity of natural fibers causes poor adhesion and wettability. Polyurethane is one of the hydrophilic polymers that would not face this kind of incompatibility. No previous research have been done for natural fiber reinforced with TPU, however TPU has been compound with synthetic fibers such as glass fiber [1].

NaOH is one of the most common chemical treatments used to clean fiber surface and enhance its properties. NaOH can help get rid of the undesirable hemicelluloses and lignin materials that cover the surface of the fibers, therefore it contributes to producing rough surface for a better mechanical interlocking with the matrix. It also changes the fine structure of the native cellulose I to cellulose II by a process known as alkalization [2]. The pMDI isocyanate, with the NCO active group can react with the most materials that have active hydrogen groups [3]. In the case of natural fiber composites it will react with the hydroxyl group available in the cellulose. Isocyanate has been used as a compatiblizer for this reason [4,5].

Kenaf plant is an annual plant that can be harvested 2-3 times a year. It can grow to reach 3-4 meters within 4-5 months. Kenaf plant has three layers bast, core, and pith. Kenaf bast represents one third of the

+ Corresponding author. Tel.: + (6-0176211554).
E-mail address: (y_shekeil@yahoo.com).

plant. Core and pith represent the rest. Kenaf bast fiber has been reported to have superior mechanical properties than the other parts of the plant [6]. The main objective of this research is to study the effect of NaOH+pMDI treatment on mechanical properties, and compare it to each treatment on its own; for TPU/KF composite.

2. Materials

Polyester based thermoplastic polyurethane (TPU) and polymeric Methylene Diphenyl Diisocyanate (pMDI) were obtained from Bayer Co. (Malaysia) Sdn Bhd, Petaling Jaya, Selangor, Malaysia. The specific gravity of the TPU was 1.21, the tensile strength was 48 MPa, the melting temperature was 210°C, and the hardness was 55D. Kenaf V36 bast fiber was supplied from KEFI (Malaysia) Sdn Bhd, Setiu, Terengganu, Malaysia.

3. Method

3.1. Fiber Preparation

Bast fiber was extracted by mechanical decortication. Fiber was pulverized using Fritsch Pulverisette mill. Pulverized fiber was sieved using an auto shaker sieve into size (125-300µm) using mesh size 50-120.

3.2. Fiber Treatment

Fibers were treated using NaOH with 2% concentration of NaOH. Fibers were soaked in the solution for 3 hours and then washed for 6 times with distilled water. Fibers were oven dried at 80°C for 24 hours.

3.3. Composite Preparation

TPU/KF composite was compounded using Haake Polydrive R600 internal mixer at 190 C, 11min and 40rpm for temperature, time and rotation speed; respectively. A 30% fiber loading was fixed throughout the study. Matrix was charged into the mixer until torque was stabilized and then fiber was added into the mixer. In case of pMDI additive; it was added into the mixer around 2min after charging the matrix.

The sample was hot pressed using Vechno Vation 40 ton compression moulding for 10 min at 190 °C. Prior to full-press, the sample was pre-heated for 7 min at 190°C. The sheet was then placed between two plates of a cold press to cool at 25 °C for 5 min.

3.4. Characterization of Composite

Tensile Testing. Tensile properties were measured using Instron 3365 machine, according to ASTM D 638. The specimens were prepared by cutting them into dumbbell shapes using a hydraulic cutter machine. Five specimens were tested with crosshead speed of 5mm/min.

Flexural Testing. Three point bending flexural test was conducted using Instron 3365 machine, according to ASTM D 790. The specimens were cut using a band saw machine with dimensions of 130 x 13 x 3mm. Five specimens were tested with a crosshead-speed of 2mm/min.

Impact Testing. Notched impact strength was measured by 43-02-01 Monitor Impact Tester according to ASTM D 256. Dimensions of samples were 63 x 13 x 3mm. At least five samples were tested. The impact strength (kJ/m^2) was calculated by dividing the recorded absorbed impact energy by the cross-section area of the samples.

4. Results and Discussion

4.1. Effect of Alkali Treatment and pMDI Additive on Tensile Properties of TPU/KF composite

Figure 1 shows the effect of alkali treatment and pMDI additive on the tensile properties of untreated composite, 2% NaOH treated composite, 4% pMDI treated composite, and 2% NaOH+4% pMDI treated composite. Tensile strength deteriorated with all treatments. Untreated composite has shown the best tensile strength of 33 MPa. The NaOH composite has shown the best result of 344 MPa of tensile modulus. The NaOH+pMDI treated composite has shown the highest strain of 75%. When using NaOH alone it reduced the strength and strain at ~ 24% and ~ 63%, respectively, however, it increased the modulus by ~ 34%. When using pMDI alone it reduced strength and modulus at ~ 21% and ~ 19%, however it increased the strain at ~ 22 %. When combined NaOH and pMDI both strength and modulus were reduced by ~ 40% and ~75%, respectively, however, strain was extremely increase by ~ 80%. Increment of strain combined with decrease of strength and stiffness is logical. The interesting observation from these results is that strain was extremely reduced when using NaOH alone; while when NaOH combined with pMDI it helped increase the strain. This strain is quite high for a composite material. This is most probably because of the increased ductility by adding pMDI and less interfacial bonding of NaOH treated fibers with the matrix. Less interfacial bonding contributes to easier fiber pullout.

4.2. Effect of Alkali Treatment and pMDI Additive on Flexural Properties of TPU/KF Composite

Figure 2 shows the effect of alkali treatment and pMDI additive on the flexural properties of untreated composite, 2% NaOH treated composite, 4% pMDI treated composite, and 2% NaOH+4% pMDI treated composite. Tensile strength deteriorated with all treatments. Untreated composite has shown the highest flexural strength and modulus of 25 and 1367 MPa, respectively. When using NaOH treatment it reduced the strength and modulus at ~ 29% and ~ 42%, respectively. When using pMDI additive it reduced strength and modulus at ~ 57% and ~ 79%, respectively. When combined NaOH and pMDI strength and modulus were reduced by ~ 41% and ~ 66% respectively.

4.3. Effect of Alkali treatment and pMDI Additive on Impact Strength of TPU/KF composite

Figure 3 shows the effect of alkali treatment and pMDI additive on the impact strength of untreated composite, 2% NaOH treated composite, 4% pMDI treated composite, and 2% NaOH+4% pMDI treated composite. The NaOH+pMDI treated composite has shown the highest impact strength of 3.5 kJ/m^2. When using NaOH treatment it reduced the impact strength by ~ 35%. pMDI treatment contributed to slight reduction of impact strength of about 9%. When combined NaOH and pMDI; impact strength increased by ~ 27%.

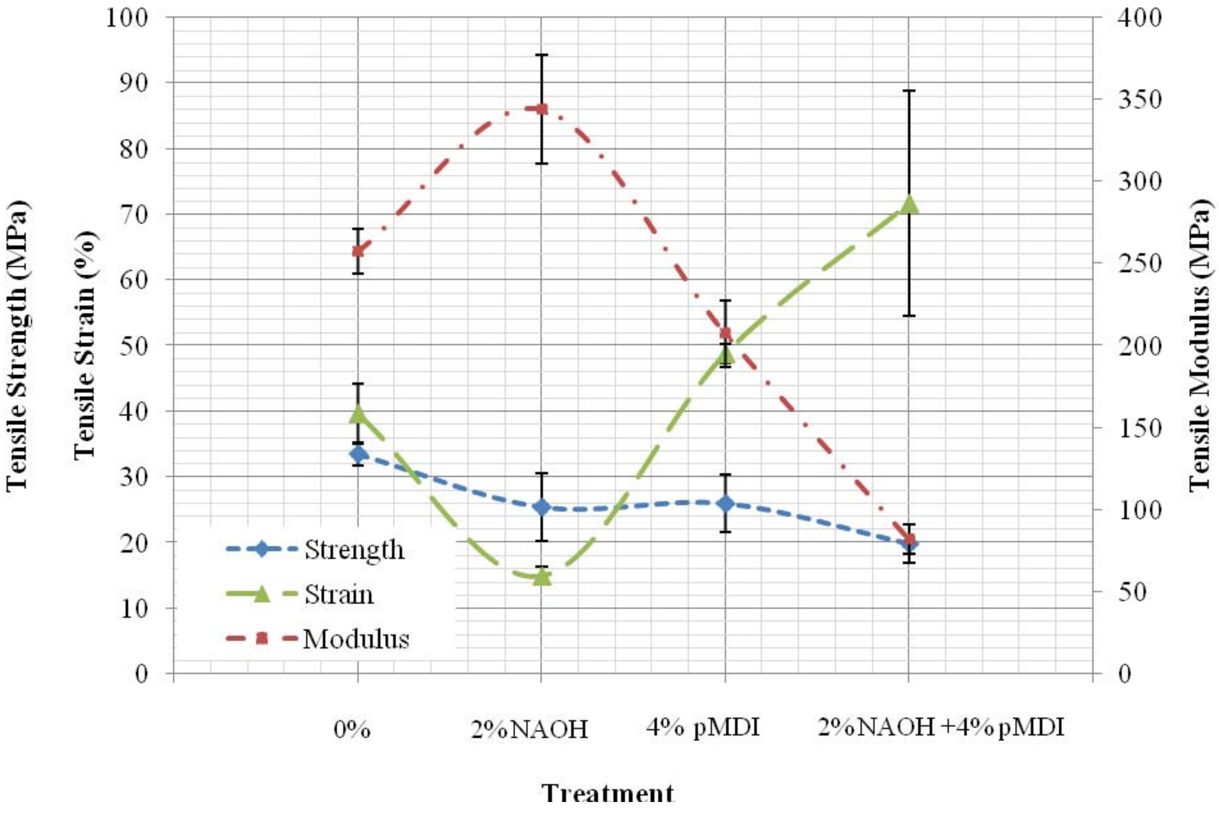

Fig. 1: Effect of treatment on tensile properties of TPU/KF composite.

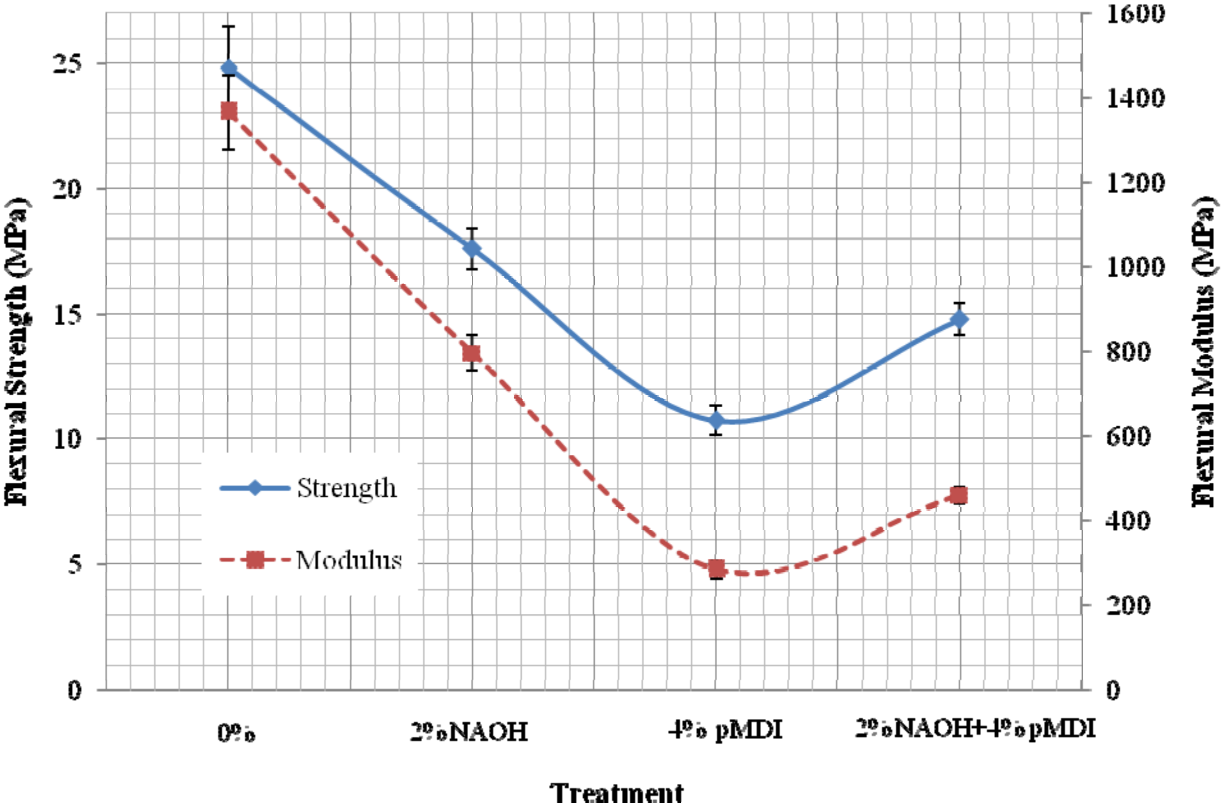

Fig. 2: Effect of treatment on flexural properties of TPU/KF composite.

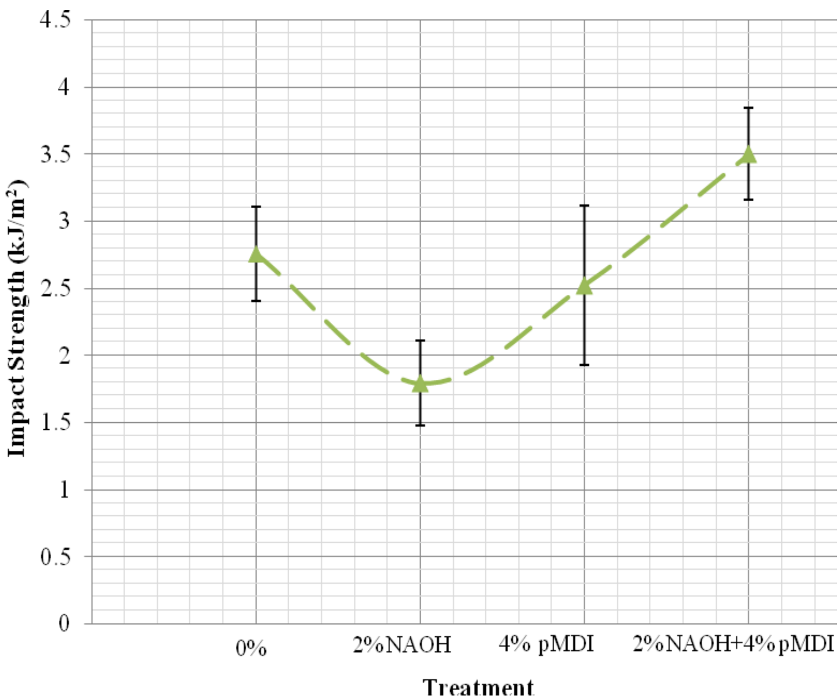

Fig. 3: Effect of treatment on impact strength of TPU/KF composite.

5. Conclusion

In conclusion the NaOH pretreated fibers have reduced the tensile strength and elongation; flexural strength and modulus and impact strength; while increased the tensile modulus only. The additive of pMDI alone did not enhance any of the properties. However, combination of NaOH and pMDI treatments resulted in increment of elongation at about 80%; i. e. it resulted in strain of 70% which is high for a short natural fiber composite. It also contributed to the enhancement of impact strength by about 27%.

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7. References

[1] S. Wilberforce and S. Hashemi. Effect of fibre concentration, strain rate and weldline on mechanical properties of injection-moulded short glass fibre reinforced thermoplastic polyurethane. *Journal of Materials Science.* 2009, 44 (5): 1333–1343.

[2] M. J. John and R. D. Anandjiwala. Recent developments in chemical modification and characterization of natural fiber-reinforced composites. *Polym Compos.* 2008, 29: 187–207.

[3] Z. H. Gao, J. Y. Gu, X. M. Wang, Z. G. Li, and X. D. Bai. FTIR and XPS study of the reaction of phenyl isocyanate and cellulose with different moisture contents. *Pigm. Resin. Technol.* 2005, 34 (5): 282.

[4] J. Girones, M. T. B. Pimenta, F. Vilaseca, A. J. F. de Carvalho, P. Mutje, and A. A. S. Curvelo. Blocked isocyanates as coupling agents for cellulose-based composites. *Carbohyd. Polym.* 2007, 68 (3): 537–543.

[5] S. H. Lee and S. Wang. Biodegradable polymers/bamboo fiber biocomposite with bio-based coupling agent. *Composites Part A: Appl. Sci. Manuf.* 2006 37 (1): 80–91.

[6] I. S. Aji, S. M. Sapuan, E. S. Zainudin, and K. Abdan. Kenaf fibres as reinforcement for polymeric composites: a review. *Int. J. Mech. Mat. Eng.* 2009, 4(3): 239-248.