Progress in Engineering Application and Technology Vol. 2 No. 1 (2021) 694-701
© Universiti Tun Hussein Onn Malaysia Publisher's Office

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Superhydrophobicity of Kapok Fiber and Its Performance in Oily Water

Muhammad Adam Bukhori Hamidon[1], **Rosniza Hussin**[1]*

[1]Department of Mechanical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2021.02.01.066
Received 13 January 2021; Accepted 01 March 2021; Available online 25 June 2021

Abstract: Kapok fiber is a normally inexhaustible material with enormous lumen and hydrophobic attributes, which empowers it to show great oil sorption limit. In order to overcome the oil spill problem by using the kapok fiber rather than synthetic fiber. In this study, kapok fiber was absorbed with various solvents, including water, lubricant oil, cooking oil, petroleum, lubricant oil 2 t and diesel. The main objective of this study is to characterized physical properties of kapok fiber, analyze super hydrophobicity properties of kapok fiber and evaluate the efficiency separation of oil-in-water emulsion using kapok fiber. The results show that the kapok fiber additionally showed high separation effectiveness for oil/water mixtures and can rapidly retain drifting oils on water surface during filtration of the oil/water mixture using kapok fiber as a filtration medium. The oil sorption capacity of kapok fiber when filter with lubricant oil, cooking oil, petroleum, lubricant oil 2 t and diesel are 22.5, 25.5, 21, 28 and 19.5 respectively. Moreover, the kapok fiber can be utilized to consistently isolate a huge quantity of oil pollutants from water surface by methods for a vacuum siphon. The discoveries recommend that the attractively super hydrophobic kapok fiber has the possibility of potential applications in the expulsion and recuperation of spilled oil toxin, implying excellent recyclability in the oil sorption.

Keywords: Kapok 1, Super Hydrophobicity 2, Oil Sorption Capacity

1. Introduction

Oil is considered to be one of the most significant energy sources in the modern industrial world. It is also used worldwide as the raw material for many chemical substances and synthetic polymer [1]. When oil is extracted, transported and processed, there is a chance of spillage which could have a major impact on the environment [2].

Once oil comes into contact with water, it creates an emulsion of oil in water or a floating film that must be drained before it is discharged into the atmosphere. Even the very low concentration of oils in traditional sewage systems can be harmful to microorganisms responsible for biodegradation [3]. With

**Corresponding author: rosniza@uthm.edu.my*

the rising discharge of oily wastewater and oil spill incidents, the separation of emulsified oil in water mixtures, in particular surfactant-stabilized emulsions, has become an urgent problem as they cause serious environmental damage and human survival [4].

Over the last decades, natural fibers received increasing attention as alternative to synthetic fibers both from academic world and various industries. Four main reasons make the natural fibers more attractive than others: i.e. specific properties, price, biodegradability and recyclability. Particularly, high specific and low density properties are nice benefits. Other than this, they are renewable and have a CO_2 neutral life cycle, compare to their synthetic competitors. The application of natural fibers is motivated by a combination of environmental sustainability, cost-effectiveness, recycling and biodegradation properties [5].

The natural fiber are one of the abundant resources that exist in nature. They are easily decomposable, biodegradable, renewable and cost effective. It can be extorted from various plant and animal resources [6]. In terms of utilization, there are two general classification of plants producing natural fiber which is primary and secondary. The primary plant are those grown for their fiber content while secondary plant are those where the fiber come as a by-product from other preliminary utilization. Primary plant such as Jute, kenaf, hemp, sisal and cotton while pineapple, cereal, stalks, agave, oil palm and coir are examples of secondary plants. Natural fibers derived from plants mainly consist of cellulose, hemicellulose, lignin, pectin and other waxy substances. In various application, natural fibers extracted from plants are used as reinforcement in both thermoplastic and thermoset composites [7].

Transporting oil from production sources to consumption locations entails risks, most notably, the risk of accidental oil spills, which can cause severe damage to ecosystems and loss to human society. The removal of crude oil and petroleum products that are spilled at sea is a serious problem for the last few decades. The absorbance method can be used in order to separate the oil-in-water emulsion. The polypropylene fiber based oil-sorbent product have been found to be mostly used to clean up oil spill. However, polypropylene is not biodegradable, hence possess environmental problem. Therefore, using a natural fiber based oil-sorbents such as kapok fiber could be an alternative method rather than using synthetic oil-sorbents. The main objective of this study is to characterized physical properties of kapok fiber, analyze super hydrophobicity properties of kapok fiber and evaluate the efficiency separation of oil-in-water emulsion using kapok fiber. Eventually, there are many natural fibers that can be used as a medium for the absorbent method. For this research, the scope is focusing only on kapok fiber. Kapok fiber is a natural fiber that can be easily obtained in south east Asian country.

2. Materials and Methods

2.1 Materials

In this study, kapok fibers have been used as material for this study. The materials have been collected from Pendang, Kedah. The oil used were lubricant oil, cooking oil, petroleum oil, lubricant oil 2t and diesel. All of the oil were purchased in Pendang. The fiber is coated with spin finish (detail are not disclosed by supplier) for easy processing. The spin finish usually contain lubricant, anti-static agent, anti-oxidizing agent, etc. Table 1 show the properties of oil. The properties show the density of different experimental oil. The density of the oils was calculated manually using equation 1:

$$Density, \rho = \frac{m}{v} \quad Eq. 1$$

ρ = Density of oil

m = Mass of oil

v = Volume of oil

Table 1: Properties of experimental oil

Type of oil	Lubricant oil perodua genuine (pg) oil sae0w-20 fully synthetic	Cooking oil (saji)	Petroleum oil (Ron 95)	Lubricant oil 2T 400 (0.5L)	Diesel oil
Mass (g)	286	295	262	290	251
Volume (cm^3)	200	200	200	200	200
Density (g/cm^3)	1.43	1.48	1.31	1.45	1.26

2.2 Methods

2.2.1 Determination of oil sorption characteristic

To evaluate the separation capacity for emulsified oil/water mixture, a series of surfactant free oil-in-water emulsion through mixing oil and water will be prepared. The oil that will be used are lubricant oil, cooking oil, petroleum, lubricant oil 2 t and diesel oil. The filtration procedures had been done as shown in Figure 1.

First step is the Lubricant Oil and water were measured precisely to 200 ml each using measuring cylinder. After being measured, both water and Lubricant oil were mix using beaker to create oil-in-water emulsion. The mixture was stirred for 2 minutes using glass rod. Then, the mixture was weighed after being stirred. A raw kapok fibre was weighed into 2 g using electronic scale. The kapok fibre that had been weighed were put into a filter funnel acting as a medium for filtration.

The equipment was arranged as shown in Figure 1. The mixture of lubricant oil and water was poured slowly through the filter funnel. The time taken to complete the filtration, level of oil-in-water emulsion and weight of kapok fibre after being filtered were recorded. The surface morphology was also recorded by using a camera. All the procedure was repeated by replacing the lubricant oil with cooking oil, petroleum, lubricant oil 2 t and diesel as shown in Table 1.

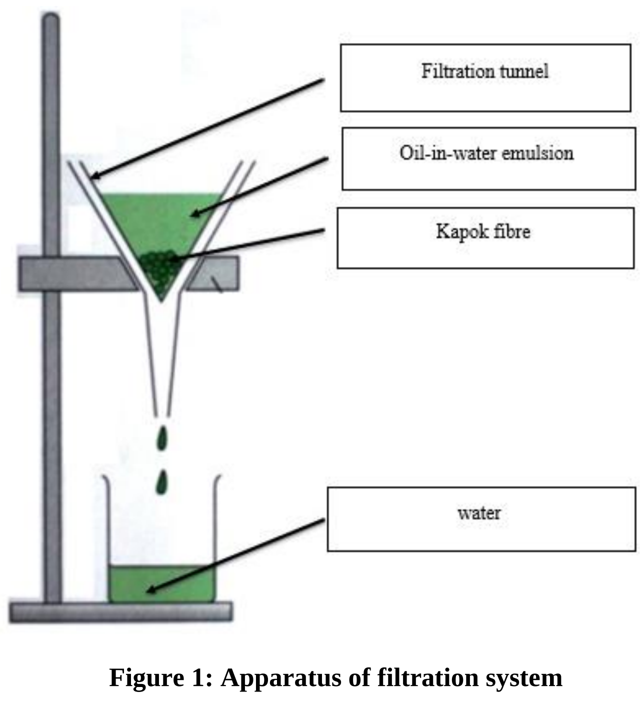


Figure 1: Apparatus of filtration system

2.2.2 Recyclability test

The super-hydrophobic kapok fibers supposedly to be immersing into the oil for 6 hours, 12 hours, 18 hours, 24 hours, and 30 hours respectively to reach sorption saturation and then placed on a sand core funnel. Then, the fiber will be drain under vacuum for 5 min to remove the residual oil and dry in an oven at 60 °C. the obtained fiber will be used for another same cycle again. The sorption/desorption cycle have been repeated. The super-hydrophobic fiber assembly connected to a vacuum system is able to continuously remove and collect a large amount of oils within a short time. More importantly, the obtained fiber is capable of separating oil-in-water emulsion with high separation efficiency.

2.3 Equations

The equation 1 have been used for oil sorption capacity calculation:

$$oil\ sorption\ capacity, Q = \frac{W_t - W_i}{W_i} \qquad Eq.2$$

Q = oil sorption capacity of the sorbents calculated as gram of oil per gram of sample.

W_t= the saturated sorbent mass (g)

W_i= the weight of dried sorbent (g)

3. Results and Discussion

3.1 Absorption Capacity

The mass of kapok fiber could be measured by using electronic scale. This properties were important because it will determine the sorption limit of kapok fiber when treated with different oil. The initial mass of kapok fiber before filtration are constant for each oil testing which is 2 g. Table 2 show the absorption capacity of kapok fiber calculated using Eq. 1.

Table 2: Absorption capacity of experimental oil

Type of oil	Lubricant oil perodua genuine (pg) oil sae0w-20 fully synthetic	Cooking oil (saji)	Petroleum oil (Ron 95)	Lubricant oil 2T 400 (0.5L)	Diesel oil
Mass after filtration (g)	47	53	44	58	41
Oil sorption capacity, Q	$\frac{47-2}{2}$ = 22.5	$\frac{53-2}{2}$ = 25.5	$\frac{44-2}{2}$ = 21	$\frac{58-2}{2}$ = 28	$\frac{41-2}{2}$ = 19.5

3.2 Comparisons of oil sorption performance

The oil sorption capacity of kapok fiber on different oil are shown in the Figure 2 below. Based on Figure 2 and Table 2, we can observe that the kapok fiber exhibit low adsorption capacity when treated with diesel compared to other experimental oil with only 19.5. While kapok fiber exhibit higher adsorption capacity towards lubricant oil 2 t with 28. Kapok fiber show higher sorption capacity for high density oil compared to diesel and petroleum. This was obviously attributed to the fact that the high density oil was heavier than the petroleum and diesel oil. The density of the high-density oil such as lubricant oil (1.43g/cm^3), cooking oil (1.48 g/cm^3), lubricant oil 2 t (1.45 g/cm^3) while the density of petroleum oil (1.31 g/cm^3) and diesel oil (1.26 g/cm^3) as shown in Table 2. Petroleum and density oil are considered low density oil.

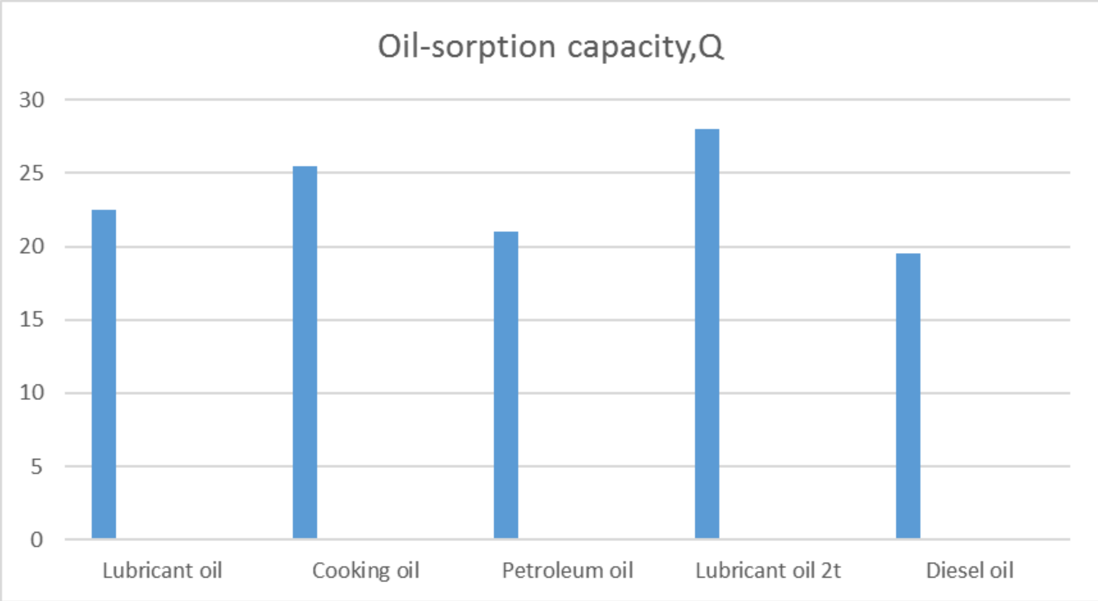


Figure 2: Oil sorption performance of experimental oil

The adsorption capacity of kapok fiber will also increase if the density of the oil increased. Super hydrophobic surfaces refer to surfaces that are highly hydrophobic with contact angle of a water droplet exceeding 150 °. Therefore, kapok fiber only absorbs oil rather than water. The adsorption capacity of kapok fiber also affected by the viscosity of the oil.

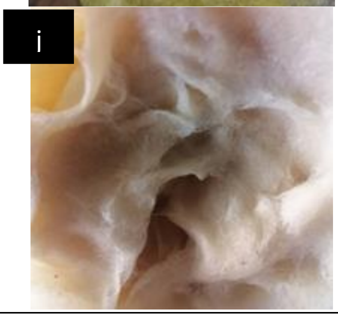
Raw kapok fiber tends to absorb high density oil such as lubricant oil 2 t compared to diesel because it has higher viscosity which means that the intermolecular force of lubricant oil 2 t is much stronger than diesel. After the lubricant oil were absorbed by kapok fiber, the liquid bridge with similar stability degree will be formed in any kind of fibers assembly. As the increase in oil concentration, the sorption capacity of the sorbents also increases until they reach an equilibrium. During the sorption process, the floating oil was absorbed quickly into fibers and almost no dispersion of oil was observed once the sorbent was added in oil and water mixture [9].

The physicochemical characteristics of kapok fibers, such as surface wax, surface roughness, the hollow lumen, porosity, and fineness, could all affect oil sorption performance The large lumen in kapok fiber plays an important role in maintaining its porous structure for oil absorption, while the high content of surface wax on the fiber surface makes it extremely hydrophobic and oleophilic [8].

3.3 Surface Morphology of Kapok Fiber

Table 3 show the surface morphology of kapok fiber before and after filtration have been analyzed using image capture. The properties of morphology were an important factor for oil sorption capacity because morphology define surface wettability, as mention in [10].

Table 3: Surface morphology of Kapok fibre before and after being treated with different oil

Before filtration	After filtration
	
	
	
	
	

The surface morphologies of raw and oil-absorption kapok fiber were shown in Table 3 above. Table 3 (f), (g), (h), (i) and (j) show the surface of the kapok fiber after being filtered with lubricant oil, cooking oil, petroleum, lubricant oil 2 t and diesel. It can be seen that the surface morphologies have changed after absorption with different type of oil-in-water emulsion. Raw kapok fiber exhibits a smooth surface without any ripple due to the coverage of plant wax, while the surface of treated samples is rough along with different degree of wrinkles and grooves. This suggests that the surface wax of kapok fiber is removed and the hydrophilic surface is exposed. As the result shown in the Table 3, the kapok fiber shown a sticky and oily behavior after being treated with different oil.

A study carried out by Wang et al [9], stated that the surface morphology of a raw kapok fiber after being analyzed using SEM has a hollow structure and smooth surface with nearly closed orifice. This indicates that the smooth fiber surface that is not in favor of the adhesion of oil is obviously improved, and the rough surface being beneficial to the adhesion of oil is generated. Besides, the increase in surface roughness of raw kapok fiber will also lead to a better locking-oil capability [9].

3.4 Review Study on Recycleability Test

A research done by Wang et al [11], stated that during the recycleability test, toluene, gasoline, and diesel were used to evaluate the recyclability of kapok fiber. In the first cycle, the oil sorption capacity of the fiber for toluene, gasoline, and diesel is 50.7, 46.8, and 56.5 g/g, respectively. After 16 cycles of sorption/desorption, the decrease of oil sorption capacities do not exceed 5.00 %. The water contact angles on the fiber surface have no obvious change after the repeated sorption/desorption. More importantly, the sorbent actually have attractive reaction even after being utilized for 16 cycles. kapok fiber displays amazing stability in toluene, gas, and diesel based on the estimation of water contact angle. There is no undeniable change in the hydrophobicity of the fiber after the drenching for various time spans. It tends to be discovered that there is no undeniable change in the water contact angle even after the kapok fiber were immersed into any of three experimental solution for 6 hour, 12 hour, 18 hour, 24 hour, and 30 hour respectively. Subsequently, it is shown that kapok fiber has a stable superhydrophobicity, magnetic responsivity, and high chemical stability can turn into a promising sorbent for oil-spill counter measure [11].

The recyclability tests were also performed as stated by Zhang et al [12]. The slight reduction in absorption capacity was supposed to result from the smaller volume of reused 0.2KCA0.2 (11.85 % decrease), and the lower porosity, which was high to 99.54 % before the reusability test, decreased to 99.48 % after 10 times reuses. Moreover, the dry weight of 0.2KCA0.2 did not change obviously and it could still float on the water surface after repeated use, which proves that 0.2KCA0.2 has long-lasting morphological stability and hydrophobicity. These results indicate that the 0.2KCA0.2 have good recyclability [12]. 0.2KCA0.2 also known as kapok/ micro-fibrillated cellulose aerogels.

4. Conclusion

The present study show that the kapok fiber suggested to be the best filtering medium for the separation of oil-in-water emulsion and another alternative for cleaning the oil spill using natural fiber. A natural fiber was chosen instead of synthetic fiber because it has more advantages compared to the synthetic fiber. During this study, the physical properties of the kapok fiber had been analyzed by using image capture. Based on the result, kapok fiber was characterized before filtration which is raw kapok fiber has a smooth-looking surface. The super hydrophobicity of kapok fiber and it efficiency separation of oil/water mixture had been presented by calculating the oil sorption capacity of kapok fiber. We can conclude that raw kapok fiber has a better oil sorption capacity when tested with high density oil compared to the low density oil such petroleum and diesel.

As for the recommendation, in order to totally isolate the water, the oil/water mixture should be filtrated various time utilizing kapok fiber as a filtration medium. Likewise, the fiber was fit for holding a large portion of oil sorption limit even after being used. For a better and more accurate analysis in the future for the surface morphology of kapok fiber and characterization of contact angle, it is recommended to use contact angle measurement tool, X-ray diffraction (XRD) measurement machine and Field Emission Scanning Electron Microscope (FE-SEM).

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] R.S. Rengasamy et.al., "Study of oil sorption behavior of filled and structured fiber assemblies made from polypropylene, kapok and milkweed fibers," J. Hazardous Materials., Vol. 186, Issue 1, pp 526-532, 2011, https://doi.org/10.1016/j.jhazmat.2010.11.031

[2] T. R. Annunciando, T.H.D. Sydenstricker, S.C. Amico, Experimental Investigation of Various Vegetable fibers as sorbent materials for oil spill, Mar.Pollut. Bull. 46 (2005) pp 780-783.

[3] J. Fei, L. Chaolin, L.D. Xiaoqing, L. Yang & W. Dandan, Separation of Oil from oily wastewater by sorption and coalescence technique using ethanol grafted polyacrylonitrile, J. Hazard. Material.164, (2009), pp 1346-1351.

[4] Chenyang Cao & Jiang Cheng, "Fabrication of robust surfaces with special wettability on porous copper substrates for various oil/water separations," J. Chemical Engineering, V. 347, pp 585-594, 2018, https://doi.org/10.1016/j.cej.2018.04.146

[5] K. Arun Kumar, S. Madhu Sudhanan, K. Mahesh Kumar & G. Ranjith Kumar, "A Study on Properties of Natural Fibres - A Review," J. Engineering and Technology, V. 04 Issue: 10, pp 1343-1350, Oct. 2017

[6] R. Jeyapragash, V. Srinivasan & S.Sathiyamurthy, "Mechanical Properties of Natural Fibre/Particulate Reinforced Epoxy Composites-A review of the literature," 2020, https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2Fj.matpr.2019.12.146

[7] Debes Bhattacharyya, Aruna Subasinghe, Nam Kyeun Kim, "Chapter 4 - Natural fibers. Their composites and flammability characterizations," Multifunctionality of Polymer Composites, William Andrew Publishing 2015, pp 102-143

[8] T. Dong, F. Wang, G. Xu, "Sorption kinetics and mechanism of various oils into kapok assembly," Marine Pollution Bulletin 9, pp 230–237, 2015, https://doi.org/10.1016/j.marpolbul.2014.11.044

[9] J. Wang, Y. Zheng, A. Wang, "Investigation of acetylated kapok fibers on the sorption of oil in water," J. Environmental Sciences 2013, Vol. 25(2) pp 246–253, 2012, https://doi.org/10.1016/j.indcrop.2017.06.059

[10] M. Zamparas, D. Tzivras, V. Dracopoulos & T. Ioannides, "Application of Sorbents for Oil Spill Cleanup Focusing on Natural-Based Modified Materials: A Review," 2020, http://dx.doi.org/10.3390/molecules25194522

[11] J. Wang, G. Geng, X. Liu, F. Hana, J. Xu, "Magnetically superhydrophobic kapok fiber for selective sorption and continuous separation of oil from water," J. Chemical Engineering Research and Design, Vol. 115, pp 122–130, 2016, http://dx.doi.org/10.1016/j.cherd.2016.09.032

[12] H. Zhang, J. Wang, G. Xu, Y. Xu, F. Wang, H. Shen, "Ultralight, hydrophobic, sustainable, cost-effective and floating kapok/ microfibrillated cellulose aerogels as speedy and recyclable oil superabsorbents," J. Hazardous Material, Vol. 406, 2021, https://doi.org/10.1016/j.jhazmat.2020.124758.