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RESEARCH

Effect of Sunflower Seeds Husk, Peanut Shell Husk and Vegetable Oils on the Tribological Performance of Basalt Chopped Fiber Reinforced Epoxy Hybrid-Composites

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ABSTRACT

Natural fiber and fillers in hybrid materials have been attracting extra attention of researchers during recent years for enhancing properties/behavior of polymer composites. Because of their lightweight, high thermal stability and safe environmental impacts sunflower husk and like fillers are proposed to improve the tribological performance of reinforced polymer hybrid composites in several studies by researchers and scientists. In the present work sunflower husk and peanut shell powder are used as natural fillers besides sesame and castor oils to improve the tribological performance of basalt fiber reinforced epoxy composites. Epoxy resin reinforced with 30% vol. basalt chopped fiber has been used for the purpose of enhancing mechanical strength, hardness, and stiffness of composites. Natural fillers and vegetable oils were added in a volumetric ratio up to 20 % interchangeably. Friction coefficient and wear rate of epoxy hybrid - composites were measured under dry sliding condition by means of Block-on-Ring (BOR) tribometer. Hardness was also investigated for the proposed polymer composites. Results show that friction coefficient of basalt reinforced epoxy hybrid –composite remarkably improved with adding of natural fillers as well as vegetable oils. For tribological applications that require low friction coefficient and high wear resistance, like solid lubricants or self-lubricated materials; epoxy hybrid-composites filled with 10 % peanut shell husk fillers as well as 10 % sesame oil have been recommended.

1. INTRODUCTION

Using of lignocellulose fillers from the agricultural industry, characterized by the presence of oil in its structure, is an interesting concept and it would be possible to obtain self-lubricating composites due to the long-lasting oil migration from the filler effect. Epoxy hybrid-composites reinforced with fiber and filled with tribological properties modifying natural fillers and oils have been proposed as alternative engineering materials for different industrial and daily life applications. For these types of engineered materials the final properties varies from the properties of each individual, which recommend it for a wide range of industrial applications. For solid lubricant purposes, polymer composites attract a lot of interest from researchers and technicians that focus on the improvement of frictional behavior and wear resistance but unfortunately, there is still a weakness in the mechanical properties of those materials. Because of its environmental friendliness impact, natural fibers, fillers and other additives like date palm seed, mango dry leaves orange peel wastes were proposed as tribological performance enhancer as well as improving mechanical behavior of polymer composites [1-4]. It was concluded that friction coefficient of carbone fiber-reinforced epoxy remarkably decreases by means of using molybdenumdisulfied nano powder [5], nano-carbon [6] as tribological performance modifier filler and to improve wear resistance. Mechanical properties, stiffness and hardness improved in epoxy composites by addition of natural fillers as walnut shell, hazelnut shell, and sunflower husk [7]. Selecting of main contents of hybrid materials has been considered as a very important issue that affect the final properties of produced composites, Han et. al. [8,9]. Besides, the fabrication method of composites significantly affect the final behavior of generated composites, Rudawska et.al [10,11]. Epoxy resins are liquid thermosetting plastics and they usually change to the solid state in the curing process [12]. Reinforcing of epoxy resins by means of good mechanical, thermal electrical and chemical fibers like basalt, glass, carbon and other specific natural fibers is a popular way to improve the properties of the brittle epoxy matrix [13-15,26-28]. Siva et al. [16] concluded that using of cashew nut shell, hazelnut shell or basalt fiber as epoxy composite reinforcements improved its thermal and mechanical properties. Even though epoxy composites depict encouraged tribological performance it remains difficult to recycle. D. Matykiewicz et al proposed that using of high content of natural additives would reduce their negative impact on the natural environment [17]. It was proposed that Sunflower husks provide low moisture for industrial and energy applications [18]. N. Saba et al. [19] pointed to using of nano oil palm empty fruit bunch fillers with epoxy composite which improved composites tensile strength. Using of basalt fiber combined with flax fiber is recommended to improve environmental and mechanical performances of polymer composites [20]. Waste fibers of hemp as eco-filler were used to improve mechanical and thermal properties of polymeric composites. It was concluded that these natural additives promote sustainability of the plastic industry and increase the amount of environmentally friendly polymer composites [21,22]. In the present work sunflower husk, peanut shell powder are used as natural fillers besides sesame and castor oils to improve the tribological performance of basalt fiber reinforced epoxy composites. The proposed material would make it be possible to obtain self-lubricating composites due to the long-lasting oil migration from the filler effect.

2. MATERIALS AND EXPERIMENTS

2.1 Preparing of test specimens

Epoxy resin C21H25ClO5 (Easy Cast-Clear Epoxy) with its corresponding 'Tetrahydromethylphthalic anhydride' hardener was purchased from SACO Co. KSA to form the matrix mixture of proposed composite. The suitable ratio of resin to hardener is 1:1 as recommended from the supplier. Basalt chopped fibre are naturally resistant to ultraviolet (UV) and high-energy electromagnetic radiation, maintain their properties in cold temperatures, and provide better acid resistance. Basalt is 100 percent inert, that is, it has no toxic reaction with air or water, and is non-combustible and explosion proof [29]. Basalt fibre of 10 mm in length was used as reinforcement with 30 % constant volumetric ratio. Two types of natural fillers: Sunflower seeds husk (SFSH) and Peanut shell husk (PSH) were collected, cleaned and dried for 8 hours under 120 C°, then grinded in the form of fine power ≤ 100 μm by the ball mill. Sunflower seeds husk (SFSH) and Peanut shell husk (PSH) fillers were mixed with two types of vegetable oils: Sesame and Castor oil by interchangeable ratio ranged from 0 to 20 % by 5% steps, as shown in Table (1). Epoxy hybrid composite was prepared by mixing of filler with oil then added to epoxy resin and mixed again after adding of hardener to provide homogenous distribution of composite's elements. Electrical mixer (325 W) was used to perform the mixing of composite contents with medium speed (120 rpm) for 1 minute.

Table 1. Composition of test sample.

Sample No.	composition [%]					
	Epoxy Resin	Basalt Fber	Sunflower husk	Peanut husk	Castor oil	Sesame oil
S0	100	0				
S1	50	50	0			
S2	50	30	20		0	
S3	50	30	15		5	
S4	50	30	10		10	
S5	50	30	5		15	
S6	50	30	0		20	
S7	50	30	15			5
S8	50	30	10			10
S9	50	30	5			15
S10	50	30	0			20
S11	50	30		20		
S12	50	30		15	5	
S13	50	30		10	10	
S14	50	30		5	15	
S15	50	30		5		15
S16	50	30		10		10
S17	50	30		15		5

After good blending it was poured in the rectangular mold that contains basalt fiber, then the mold was closed and continuously rotated biaxial in low constant speed for an hour to ensure uniform distribution of composite contents. All samples were left for 24 hour to be ready for removing from mold, cut into rectangular samples 30 x 13 x 6 mm^3 for experimental tests.

2.2 Tribological and mechanical tests

After cutting of the test sample in the required size it was polished by emery paper (grit size 1000) to achieve smooth uniform surface. Block – on- Ring (BOR) tribometer, according to ASTM G 115 & G77 standards [30,31], was used for performing tribological measurements. Friction coefficient and wear rate of test samples were measured under dry sliding conditions, constant contact pressure and sliding speed of 2 N/mm^2 and 22 m/min respectively. Steel ring with 70 mm diameter and 20 mm width was used as the counter face with 1.120 μm surface roughness to perform tribological measurements. All measurements were performed after one week of complete solidification of test samples. Friction force between contact surfaces was monitored on the digital screen by means of load cell and then the friction coefficient was calculated. Wear rate of the test samples was considered as a relation between weight loss during sliding and the applied load as well as sliding distance, as given in Eq. 1.

$$Wr = \frac{\Delta w}{p \times s} \tag{1}$$

Where:
W_r = Wear rate g/Nm,
$\Delta\ w$ = Weight loss, g,
P = applied load, N,
S = Sliding distance, m.

Hardness is a crucial factor in studying the tribological behavior of polymer composites. It plays an important role in the wear resistance of the contact area. Hardness of the basalt reinforced hybrid composites was detected according to ASTM D2240, DIN 53505, ISO 868, and ISO 7619, by Shore D Durometer.

3. RESULTS AND DISCUSSION

3.1 Effect of filler content on friction coefficient and wear resistance of epoxy hybrid-composites with addition of sesame oil

Figure 1 shows a sharp reduction in friction coefficient of basalt-reinforced epoxy with the presence of sesame oil 20% without fillers. The friction coefficient reduced from 0.92 for net epoxy (NE) to 0.38. Adding of natural fillers reduced the value of the coefficient of friction to 0.36 and 0.23 for composites filled with 5% sunflower seeds husk (SFSH) and peanut shell husk (PSH) respectively. It seems that the presence of sesame oil by a large amount 20% acts as an impregnated lubricant in epoxy composites which decreases the sticking between the contact points of composite and counterface, which reduces the friction coefficient. Friction coefficient slightly drops values with the addition of 5% natural filler. Composites filled with peanut husk powder showed low friction coefficients in comparison with that filled by sunflower seeds husk. It may be related to the physical properties of peanut husk powder that provide high carbon content which behave as a solid lubricant and decrease the coefficient of friction, according to [32].

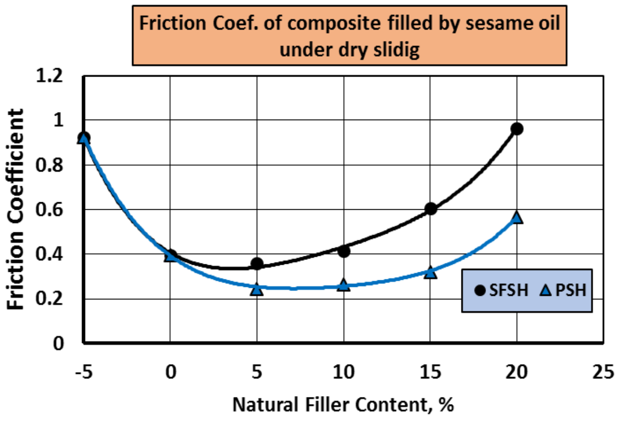

Fig. 1. Effect of natural fillers on the friction coefficient of epoxy hybrid composites filled with sesame oil.

Figure 2 shows increases of wear rate of epoxy hybrid composite without fillers to 1.2 E-05 g/Nm as sesame oil was added to basalt-reinforced epoxy in 20%. It can be interpreted as a result of low internal bonds between sesame oil and epoxy. Remarkable reduction in wear rate was observed with increase of fillers in epoxy hybrid-composite to 2E-06 g/Nm for composites filled with 15% Peanut Shell Husk. It seems that adding of natural fillers in basalt reinforced hybrid-composite mean low oil content and high internal coherent between composite contents which may be responsible for wear reduction. In some composites wear rate increased by the presence of oil content which may be related to the weakness of cross-linked between contents of composites.

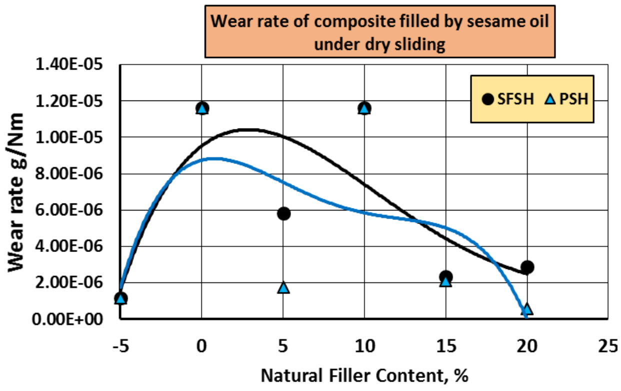

Fig. 2. Effect of natural fillers on the wear rate of epoxy hybrid composites filled with sesame oil.

3.2 Effect of filler content on friction coefficient and wear resistance of epoxy hybrid-composites with addition of castor oil

Figure 3 display the effect of castor oil as well as fillers content on the frictional behavior of epoxy hybrid-composites, for net epoxy sample – that contains no oil and no filler content. It showed high friction coefficient about 0.92. By adding of castor oil in 20% the value of friction coefficient decreases to 0.68. Increases of filler content showed significant decrease of friction coefficient to 0.38 and 0.62 for composites containing 15% peanut shell husk and sunflower seed husk respectively.

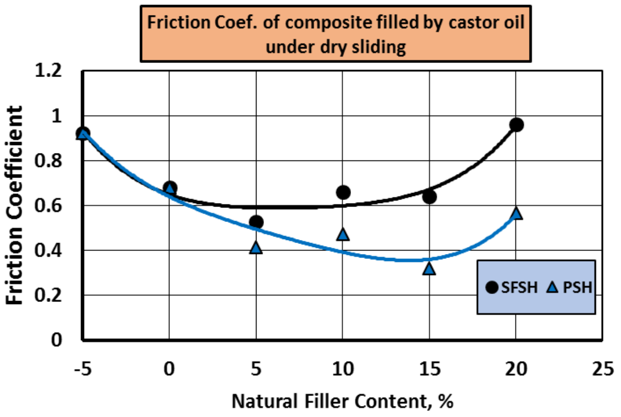

Fig. 3. Effect of natural fillers on the friction coefficient of epoxy hybrid composites filled with castor oil.

This may be the results of high conjunction between fillers and other contents that limits or prevents formation of abrasive particles on contact points that reduces wear as well as friction coefficients of epoxy composites. Besides, extra content of fillers to 20%, means no oil content and showed increase of friction coefficients. It seems that absence of oil content increases adhesive action between the contact surfaces and increases friction coefficient of epoxy hybrid composites.

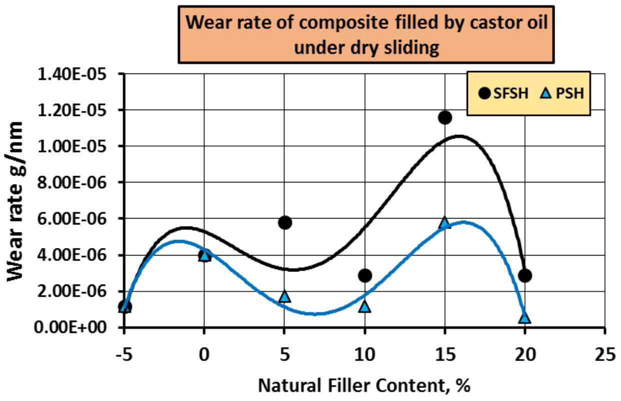

Fig. 4. Effect of natural fillers on the wear rate of epoxy hybrid composites filled with castor oil.

Figure 4 shows that wear rate of epoxy hybrid composite increases to 4 E-06 g/Nm with the presence of castor oil of 20% and no filler content which relates to low coherent between composite components. Then with adding of natural fillers the rate of wear decreased to less than 2E-06 g/Nm for composites containing 10% peanut shell husk filler. In addition, increase of sunflower seeds husk content to 10 % decreased the wear rate of composites.

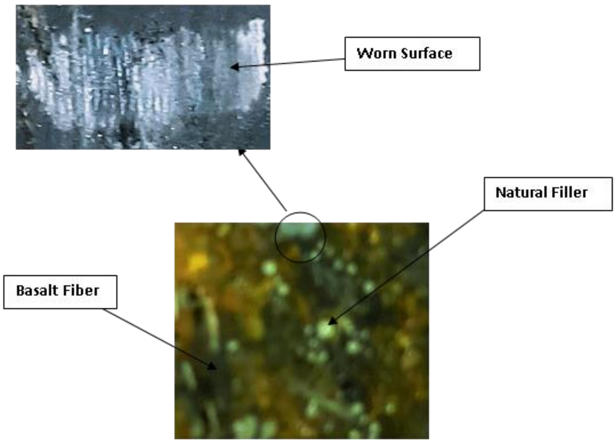

Fig. 5. Microscopic image for test sample as well as worn surface.

Comparison of effects of oil types Fig. 1 and Fig. 3 showed that friction coefficients of basalt fibre reinforced epoxy hybrid-composites filled with sesame oil are lower than the ones for composites filled with castor oils, which may be related to the difference in natural properties of each type of oil like viscosity [23-25] that is higher for castor oil than sesame oil. High viscosity oil may act as a good lubricant. On the other hand peanut shell husk fillers shows good tribological performance in comparison to the sunflower seeds that may be related to the increase of carbon content for 46% for peanut shell husk, and 41% for SFSH. Microscopic image with 20X magnification was taken for test sample as well as image for worn surface under 40X magnification, as shown in Fig. 5.

3.3 Effect of filler and oil content on hardness of epoxy hybrid-composites

Figures 5 and 6 shows the effect of natural fillers and vegetable oils on the hardness of epoxy hybrid composites. Hardness of basalt reinforced epoxy hybrid composites was measured directly on the surface of test samples at five different positions and the average values were recorded from aspect of the filler and oil content. Fig. 6 shows that increase of sesame oil slightly decreased hardness from shore D70 for net epoxy to 65D for composite containing 20 % sesame oil without fillers. Besides, increase of PSH fillers to 20% increased the hardness to 70D again.

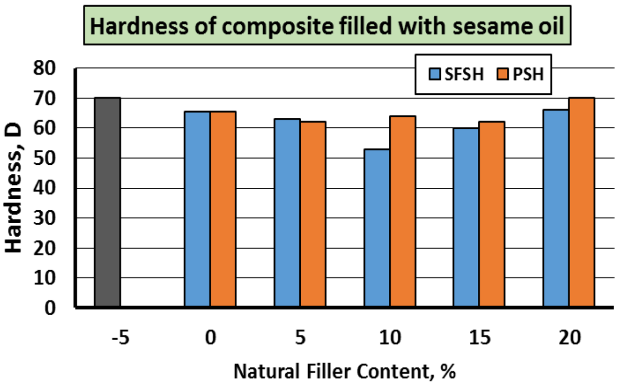

Fig. 6. Effect of natural fillers on hardness of epoxy hybrid composites filled with sesame oil.

The same trend is shown in Fig. 7. Increase of castor oil decreased hardness of epoxy composites and increase of filler content increased epoxy hybrid-composites hardness. Fourier Transform Infrared Spectroscopy (FTIR) is largely used for the study of organic molecules: stretching vibration cause change in the bond length and bending vibration cause change in the bond angle. Change in the bond length usually occurred at higher frequency or energy because stretching requires higher energy as compared to bending vibrations. According to Hooke's law, the atoms with high mass will produce low frequency vibration or lower energy [33-35]. Figs 8, 9 shows the results of FTIR measurements for castor oil, sesame oil, sunflower seeds and peanut seeds, whereas the most common bonds in the molecules are C-C, C-H. For the FTIR spectrum of compounds containing C-H and C-C bonds, the stretching vibration of C-H (2900 cm^{-1}) appeared at higher frequency as compared to C-C at (1200 cm^{-1}); the same order is true for bending vibrations which means these are the organic molecules.

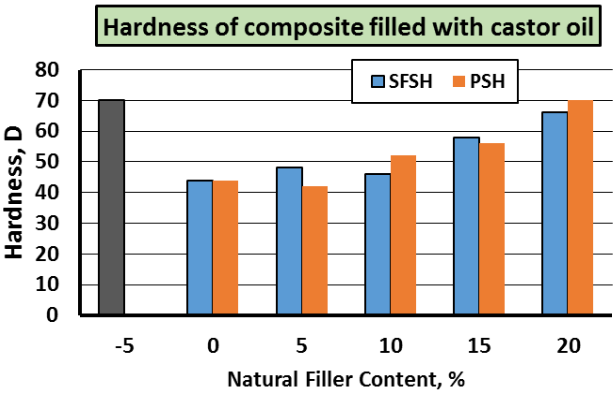

Fig. 7. Effect of natural fillers on hardness of Epoxy hybrid composites filled with Castor oil.

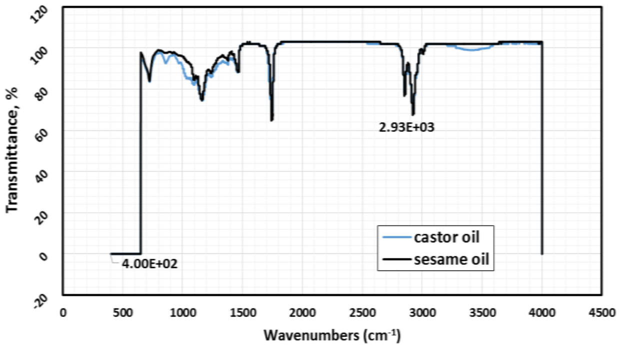

Fig. 8. Fourier Transform Infrared Spectroscopy FTIR for castor and sesame oil.

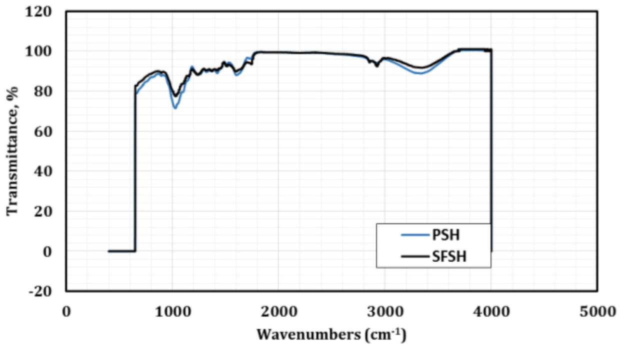

Fig. 9. Fourier Transform Infrared Spectroscopy FTIR for sunflower seeds and peanut seeds.

4. CONCLUSION

From this experimental work and its results, we can conclude that:

1. Friction coefficient of basalt reinforced epoxy hybrid–composite remarkably improved with adding of natural fillers as well as vegetable oils
2. Peanut shell husk filler significantly reduces friction coefficient and wear rate of epoxy hybrid-composite.
3. There is little enhancement on wear resistance of epoxy hybrid-composites when adding sesame oil.
4. Hardness of epoxy composites decreases with increase of vegetable oils percentage.
5. Castor oils are better friction reduction additives for epoxy composites.
6. For tribological applications that require low friction coefficient and high wear resistance, like solid lubricants or self-lubricated materials, epoxy hybrid-composites filled with 10 % peanut shell husk fillers as well as 10 % vegetable oil are recommended.

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