Influence of treated kenaf fibers on the mechanical behavior for thermoset - based Polymer composite

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Abstract

In this research, some mechanical properties such as (flexural strength, young modulus and wear rate) have been studied to the composite Epoxy resin (EP) reinforced with ٥ % volume fraction of chopped kenaf fibers (KF)) by using hand lay-up technique . The natural fibers treated with ٠,٥ normality of NaOH solution. The experimental results were compared with treated fibers composite, un treated fiber composite and pure epoxy. It was found that the treated kenaf fibers have increasing in young modulus, flexural strength values of the (EP/ KF) composite, comparing with neat resin (EP), while wear rates were increased with applied load of all samples.

Keywords
Epoxy, chopped kenaf fiber, wear test, bending test, flexural strength test.

تأثير معاملة الياف الكناف على الخواص الميكانيكية لمتراكب ذو اساس بوليمر متصلد حرارياً

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الخـــــلاصة :

تم في هذا البحث دراسة بعض الخواص الميكانيكية مثل (متانة الكسر ، معامل المرونة ومعدل البلى) لراتنج الايبوكسي المدعم بـــ 5% من الكسر الحجمي لالياف الكناف العشوائية باستخدام تقنية القولبة اليدوية . لقد تم معاملة الألياف الطبيعية بمحلول هيدروكسيد الصوديوم (Na OH)

وبتركيز قدره (0.5 N) . ان النتائج العملية تم مقارنتها مع متراكب ألياف الكناف المعاملة , ومتراكب الالياف غير المعامله والايبوكسي النقي . لقد وجد أن ألياف الكناف المعاملة تزيد من قيم معامل يونك ومتانة الكسر لـــ متراكب (ايبوكسي / ألياف الكناف) مقارنة مع الايبوكسي النقي ، بينما يزداد معدل البلى مع زيادة الحمل المسلط لجميع العينات.

Introduction

Many researchers have focused their attention on natural fiber composite which are composed of natural or synthetic resins, reinforced with natural fibers. Thus, manufacturing of high-performance engineering materials from renewable resources has been followed by researchers across the world due to lower density, lower cost, non-toxicity, ease of processing, recyclability, renewable raw materials , do not cause health problem , better formability, abundant, possess tool wearing rates, thermal insulation properties, acoustic properties, sufficient energy requirements [1-3]. In spite of these features, there are many drawbacks also such as hydrophilic in nature (water absorption), strength degradation,, poor fiber/matrix interfacial adhesion and poor thermal stability of natural fibers which can be overcome by chemical treatment or compatibilizer which amended the adhesion between the fiber and matrix. Composite of polymers and kenaf fiber possess the variances and incomparability in terms of their polarity structures [3].

Kenaf is exactly known as (*Hibiscus cannabinus)* where genus is Hibiscus and family Malvaceae obtained from stems of plants [4]. It is a warm season annually herbaceous fiber crop having short day related to family as cotton and jute with the average diameter of fiber is 67.6 µm [3,5]. Kenaf is wild dicotyledons plant of subtropical and tropical parts of Africa and Asia.

Kenaf has a single, straight stem without a branch and branchless stalk , has a short plantation cycle, flexibility to environmental conditions and requires relatively lowered quantity of pesticides and herbicides when compared with other lignocellulosic fiber crops since [3,6].

Kenaf plant made up of different fibers: an inner woody core is about 60% of the stalk's by weight of the kenaf's stalk and an outer fibrous bark surrounding the core named bast, is about 40% of the stalk's [6]. Bast fibers derived from natural fibers such as hemp, flax, kenaf and jute have high specific strength, low density and are extremely concerned in several industrial applications [3].

Kenaf is a hardy, strong and tough plant with a fibrous stalk, resistant to insect damage and requires relatively fewer amount of or no pesticides and grow quickly, rising to as height as 4-5 m in within 4-5 month growing season with the kenaf's stalk diameter of 25-35 mm [7,8].

Fig. (1) Typical images of (A) kenaf plantation and (B) kenaf fiber [3].

Kenaf fibers are increasingly extensive throughout the world and even in Malaysia as the significant natural materials source contributing towards the development of eco-friendly assets to produce twine, rope and sack cloth , automotive, sports industries, food packaging and furniture, textiles, building materials, decking, absorbents , animal feeds and board industry [3] [1] . In addition to its utility, kenaf has attracted attention in recent decades in the field of fiber reinforced composites. Many properties of the natural fiber reinforced composites were comparable or superior to those of the glass fiber reinforced composites. It was found that tensile modulus, impact strength and the ultimate tensile stress of the kenaf reinforced polypropylene composites were positive to the fiber content [9].

Many investigations have focused on the treatment of fibers to improve the bonding with resin.

Tao, Moreau and Calamari (1995) studied properties of nonwoven mats of kenaf fibers which treated with sodium hydroxide to extract lignin and separate the fiber bundles and found that finer fibers were obtained with increasing the concentration of sodium hydroxide [10].

Yang *et al* ., (2001) explained carding of kenaf increased break up the fiber bundles after the chemical processing of kenaf fibers and softer treatment of the kenaf fibers under indifferent condition after alkali extraction helps to get finer fibers to pass through carding machine, with nearly no bad effect on the fiber strength [11].

Yousif *et al* ., (2012) reported on flexural properties of unidirectional long kenaf fiber reinforced epoxy composites and the results shown that reinforcement of epoxy with treated kenaf fibers with 6% NaOH solution increased the flexural strength of composite by about 36 % , while , untreated fibers introduced 20% improvement [12].

V. Fiore *et al* ., (2015) studied the effect of alkaline treatment with 6% NaOH solution on mechanical properties of kenaf fibers and their epoxy composites; the result showed that the chemical treatment for 48 h allowed to clean the fibers surface removing each impurity ,while, 144 h of immersion time had damaging effect on the fibers surface and on their mechanical properties. All composites showed higher moduli than epoxy resin by using unidirectional long fibers as reinforcement , only the composites reinforced with unidirectional layers showed higher strength compared to the neat resin , the chemical treatment for 48 h improved the mechanical properties of the composites whichever fabric is used as reinforcement [13] .

Recently, kenaf in Malaysia has been identified as one of the potential natural raw fibers to replace tobacco in manufacturing a multitude of products for the construction, automotive, textile and advanced technology sectors.

The aim of this research is to study the mechanical properties such as young's modulus, flexural strength and wear rate properties of untreated and treated kenaf fiber reinforced epoxy composites.

Experimental work

1- Matrix Material (Epoxy resin EP)

Epoxy resin (Quick-mast 105) was used in this research. It is a liquid with moderate viscosity and capable to be converted to solid state by adding the solution (Metaphenylene Diamine, MPDA) as hardener with density (1.04 g/cm^3). This hardener is a light liquid with yellowish color, the ratio of this hardener to the epoxy is about (1:3). The characteristics of this epoxy can be briefed as follows: high adhesion to fibers, high electrical insulation, high chemical resistance, low shrinkage and high mechanical properties.

2-Reinforcing Material (kenaf fiber KF)

Kenaf fiber preparation:

Kenaf fibers are collected from kenaf plant in Malaysia by extracting from kenaf plant using manual or mechanical extraction procedure .Here chopped fibers with density (1.4 g/cm^3) are used to fabricate the natural fiber composites. First the supplied fibers were cleaned in the distilled water and dried in the sun light. The dried natural fibers are again cleaned by chemical cleaning process. In chemical cleaning process the 80% sodium hydroxide is mixed with 20% distilled water. The dried natural fibers dipped in the diluted sodium hydroxide solution. It's again dried in sun light .The dried natural fibers are cut manually. The cut natural fibers are used to fabricate the natural fiber composites. Portion of cleaned fibers socked in with (0.5 normality) of NaOH solution for half an hour at room temperature to remove the unwanted soluble cellulose, hemi cellulose, pectin, lignin, etc from the fiber , The fibers were then washed with distilled water until the NaOH was removed. After washing, the fiber was air dried for 2 days. Next, the fiber was kept in an oven at 100 ^oC for 6 h before use.

Preparation Technique:

Hand lay – up molding was used for preparing the samples under test, first a mold prepared in advance and made of vulcanized iron with dimension (15 x 10 x 0.5) cm^3. The base of mold must be cleaned very well before casting and must be covered with oiled material for getting the sample easily. Three samples were prepared as follows:

1- Pure epoxy: EP resin was mixed gradually by glass rod with its hardener at ratio of (3:1).

2- (EP / KF) composite: Short kenaf fibers were added gradually to the epoxy resin with continuous mixing to obtain 5% volume fraction of kenaf fibers.

3- (EP/ treated KF) composite when kenaf fibers were treated with NaOH solution. Volume fraction of fiber (V_f) is combined with the weight fraction (Ψ) by the relation [14]:

$$V_f = \frac{1}{1 + \frac{1-\Psi}{\Psi} * \frac{\rho_f}{\rho_m}} \quad ....(1)$$

Where; ρ_f , ρ_m are the density of the filler and the matrix respectively. When the solidification process is finished, the mold was taken out of the mold. Then, the curing process is done in a temperature (60°C) for 2 hours. Finally, the sample was cut down into standard dimensions according to the standard qualities for fulfilling the specific tests in the work.

Mechanical tests

Bending test

This test is named as (three points test made by Phywe Company – Germany). The bending tests were performed according to ASTM-D790 standard with dimensions of sample: length (100mm), width: (10 mm) and height: (5mm).The main purpose of this test is to find Young's modulus (E) (MPa) which can be calculated from the equation [15]:-

$$E = \frac{MgL^3}{48IS} \qquad \text{……..….. (2)}$$

Where: (*M/S*): Slope calculated from curve [mass – deflection]

g: acceleration due to gravity, its value (9.81 m /s^2)

I: momentum of geometrical bending which could be calculated from the equation [15]:

$$I = \frac{bd^3}{12} \qquad \text{……….. (3)}$$

b: width of specimen (m)
d: thickness of specimen (m)
L: distance between supports (m)

Flexural Testing

This test was carried out in accordance with ASTM D -790, three-point loading system applied on a supported beam was utilized.

The dimensions and thickness of sample were measured and recorded. The flexural strength was calculated from the following relationships [16]:

$F.S. = 3PL/ 2bt^2$ ……….(4)

Where:

F.S: Flexural strength (MPa)

P: applied force till the failure of sample occurs (N)

S: Span of sample (mm), b: width of sample (mm), t: thickness of sample (mm)

Wear test technique:

Wear rate was measured by using (Pin - on – Disc) supplied by local company named (Al furat al awsat company). The sample pin was fixed in a holder and abraded under different applied loads (5N, 10N and 15N). After each run the samples were removed from the machine and weighted accurately to determine the loss in weight. The used disc in this work is made from steel material with hardness (55HRC).

In this case, it is importance mentioning to show that the previous variables were fixed at distance (5 cm) for (2) min. The surface of all samples under study were cleaned and grinded to become smoother (without scratches) before the test.

The wear rates are calculated according to the following equation [17]:-

Wear rate (W.R) = $\Delta W/S_D$ ..…….(5)

Where:

$\Delta W=W_1-W_2$: is the weight loss of the sample before and after the wear test (gm).

S_D: is the sliding distance (cm).

$S_D = 2\pi nrt$ ..…..(6)

Where

t: is the sliding time (min).

r: The distance from the centre of sample to the centre of disc .

n: is the no. of revolutions of the rotating disc=500 (cycle /min).

Results and Discussions

1. Bending test

The relation between mass and deflection was shown in figures (1-3). From the mechanical test results, the E value of epoxy resin reinforced with treated (KF) of (1658.76 MPa) compared with that of epoxy reinforced with untreated (KF) of (1537.08 MPa). Both samples showed higher E values than the epoxy resin of (1489.47 MPa). This increasing due to good adhesion between the matrix and fibers and good dispersion of KF.

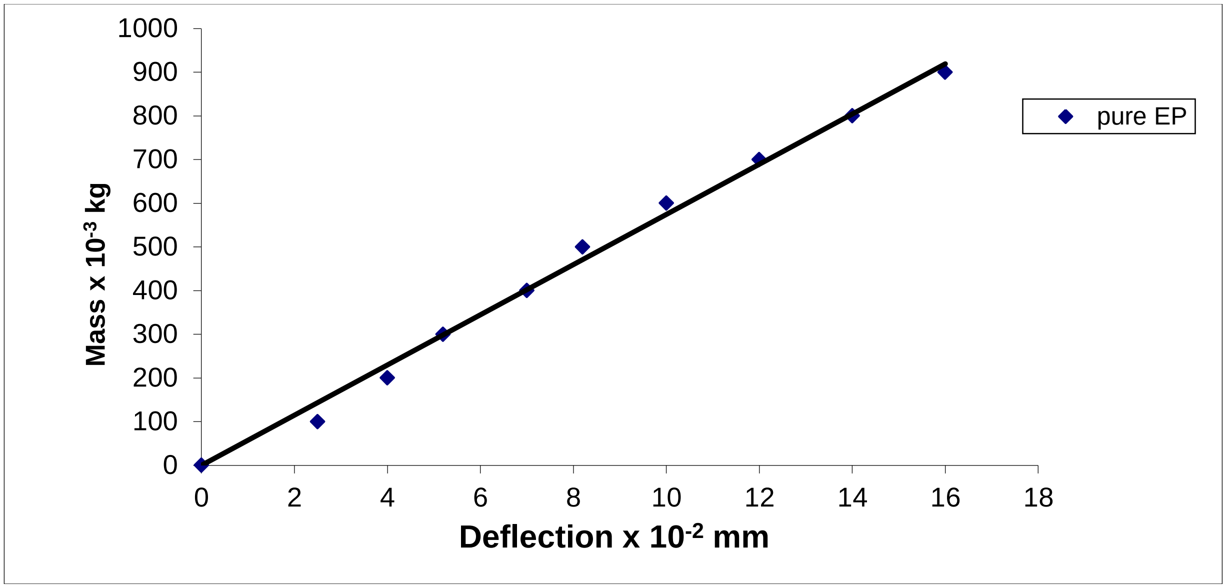

Fig (1): The relation between Mass and Deflection of pure (EP)

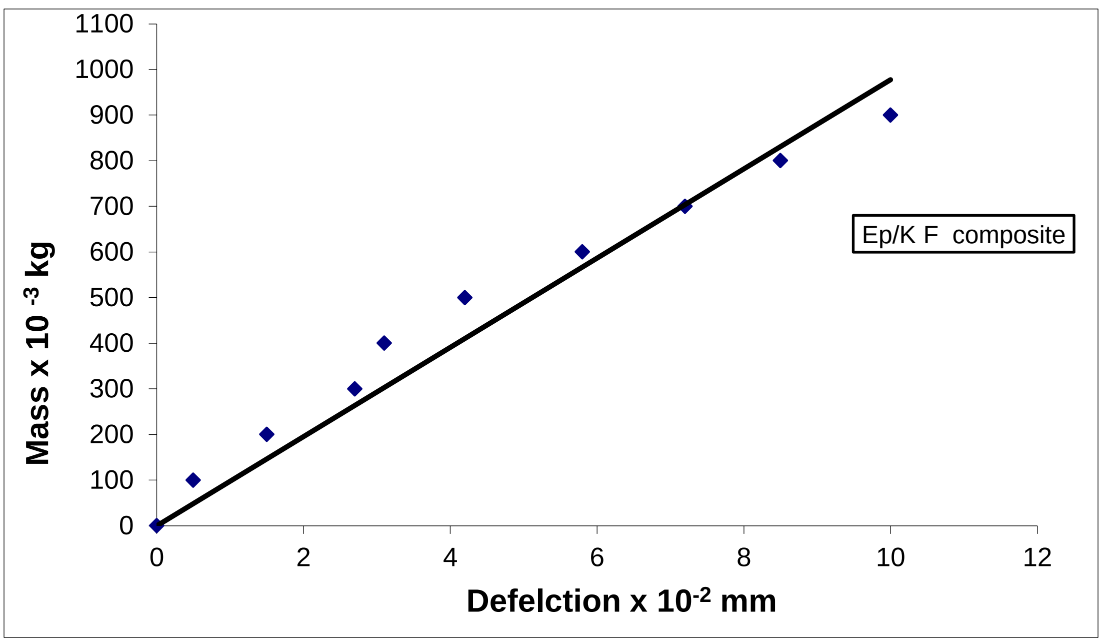

Fig (2): The relation between Mass and Deflection of (EP/KF) composite.

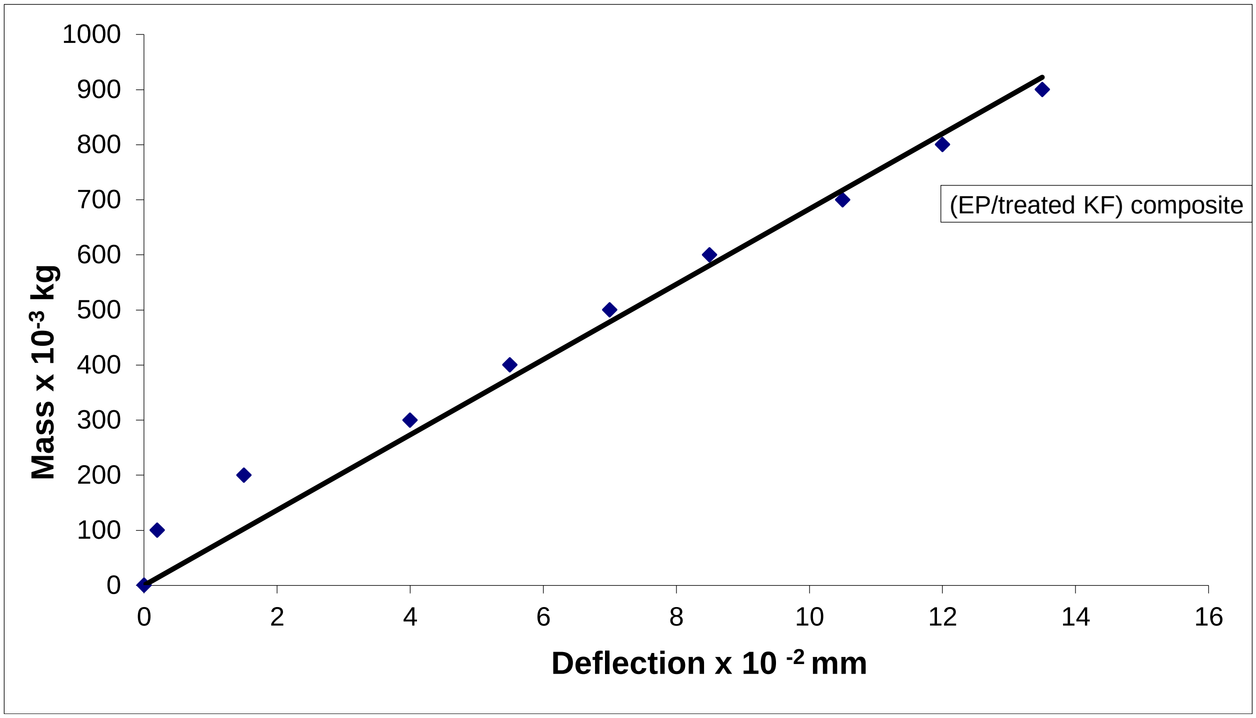

Fig (3): The relation between Mass and Deflection of (EP/treated KF) composite.

Flexural properties

Flexural properties of the pure epoxy, untreated and treated composites were displayed in Fig.(٤) . It can be concluded that there was an increase in flexural strength for both treated and untreated fiber composite compared to pure epoxy.

This could be due to two reasons the first is the treatment lead to enhance the interfacial adhesion of the fiber with the matrix and allowing the resin to enter the fibers' bundle during the manufacturing process.

Jayaramudu , *et al.* reported that the fiber damage is more in untreated fiber-reinforced composites when compared with the alkali-treated fiber-reinforced composites. The alkali treatment by removing hemicellulose and lignin contents from the fiber yields the higher percentage of (alpha α) cellulose in natural fibers[18].While Yan , *et al.* concluded that Chemical analysis revealed that after alkali treatment, the percentage of α-cellulose of Roystonea regia fiber increased from 58 to 65%. This will render the fiber surface coarser, leading to better interface between matrix and fiber. Alkalization also causes fibrillation, i.e. breaking of fiber bundles in to smaller fibers, which would increase the effective surface area available for wetting by the matrix material [19].This is corresponding with current study.

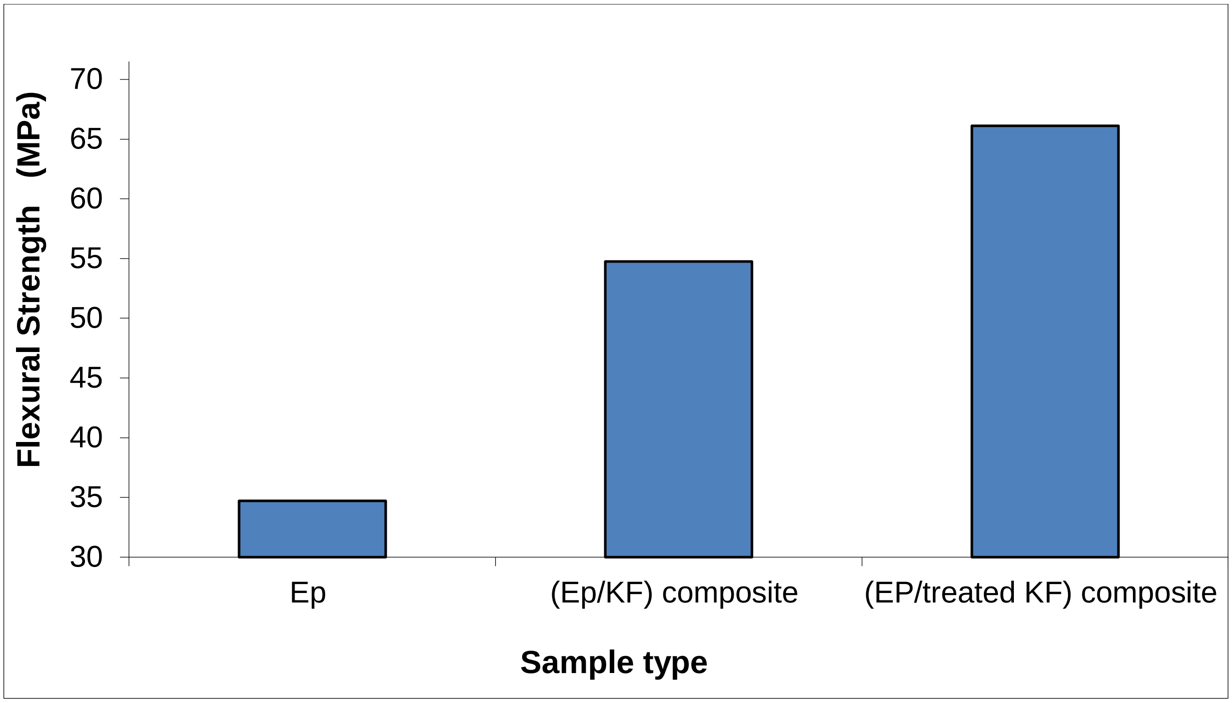

Fig (4) Variation of flexural strength values with sample type.

Wear test

The relations of wear rate (W.R) versus applied load for EP resin and it composites are shown in Fig. (5) respectively.

From Fig. (5) which showed that wear transmission from (Transition wear stage) to the (Sever wear stage) of pure epoxy, and this shows that the wear increased with increasing load, while the composites transferred from (Transition wear stage) to (Mild wear stage).

The wear rate increases with increase of the applied load for epoxy resin apart. This result is corresponding with the study with the results of the researcher (Raghad) as she concluded that the wear rate of pure epoxy increases with the increase of applied load [20].

The results of experimental tests showed that the increase of load led to increase wear rate due to increase friction forces and the reason for this is that the friction force (F) corresponding with the force required (N) as relation below [21] .

$F \alpha \ N$ ……….(7)

$F = \mu \ N$ ……….(8)

Where μ : Coefficient of Friction

In addition of increase temperature between the sample and the disk surface, both of friction surfaces consists of protrusions and grooves, and the beginning of the contact between both of surfaces happens at sharp protrusions, and under the influence of applies load the stress is concentrated on sharp protrusions which lead to a plastic deformation of these outcrops and the increasing of load was lead to increase distortion which happen at top of protrusions and near the region of surface and increase the pitting due to effect of result particles from the crash surface and the small cracks were gather with each other leading to remove the surface layers composed of debris look like thin particle therefore the plastic deformation is increased with increase load [21] .

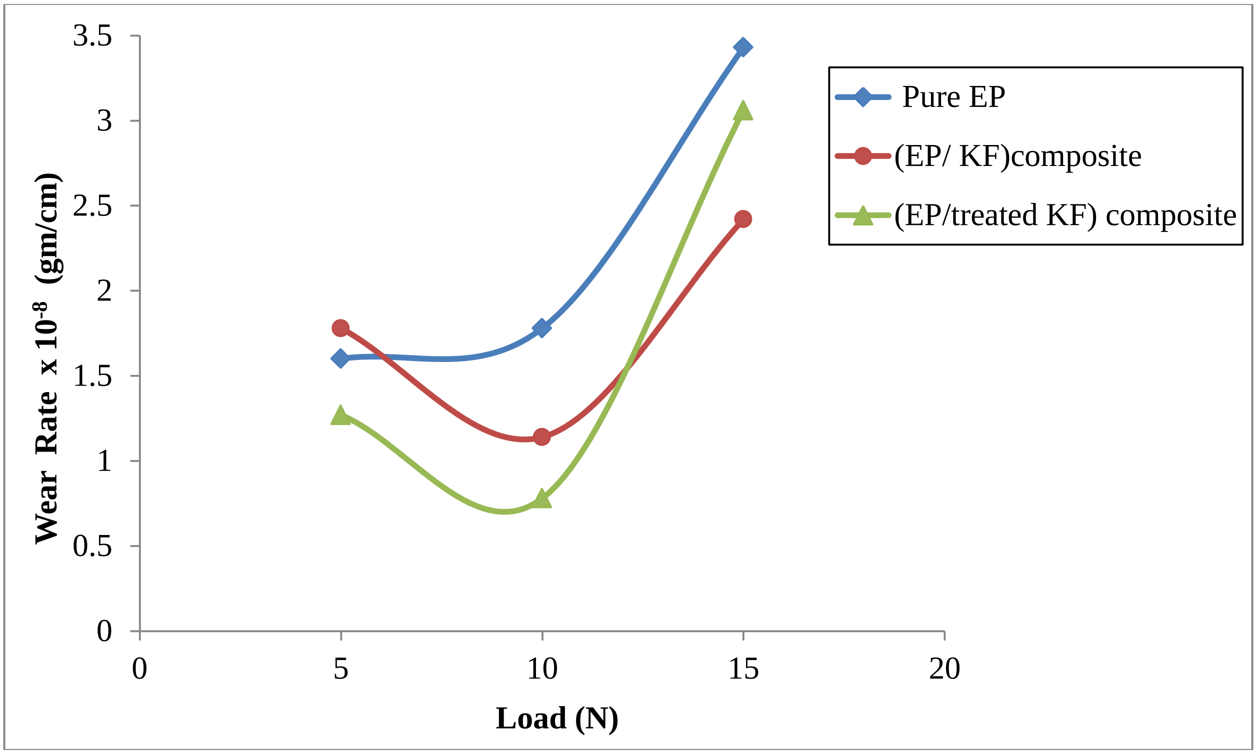

Fig (5) Variation of wear rate values with applied load of pure (EP) and it **composites.**

Conclusion

– The alkali treatment of kenaf fibers influences the flexural properties, young's modulus, wear rate of composites whichever fabric is used as reinforcement, due to improvement of the fibers–matrix compatibility.

– All the composites show higher flexural strength than pure epoxy resin.

– All the composites show higher young's modulus than pure epoxy resin.

– Wear rate values were increased with increasing applied load for all sample.

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