



Influence of Self Adhesion Mechanical and Physical Properties of Palm Trees Fibers - Polystyrene Composites

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Abstract

Polystyrene (PS) composites containing different concentrations of Palm Trees Fibers (PTF/PS) have been prepared by hot mixing process using Plasti Corder machine. PTF surface have been treated by PS solution to optimize the adhesion between PTF and PS in PTF/PS composite. The study of the abrasion, water absorption and the mechanical properties of the treated and untreated PTF/PS composites showed a significant improvement for the treated composites. The value of the modulus of the elasticity increased by the PS solution treatment from 1.1 GPa to 3.45 GPa for 60% fiber concentration in PTF/PS composites.

Keywords: palm trees fibers, polystyrene ,adhesion, wood polymer composite

1. Introduction

Wood polymer composites (WPC) are used in recent years in construction such as decking, docks, landscaping timbers, fencing, etc. instead of natural wood because of the renewability and recyclability as well desirable physical and mechanical properties [1]. The natural organic fillers such as lignocellulose fiber have been used because of their advantages relative to most common mineral fillers. These include high specific stiffness and strength, availability, lower density, lower cost, low hardness which minimize wear of processing equipment, renewability, and recyclability [2-11].

The important factors for polymer reinforcements are the size and specific area of filler particles, chemical composition of their surface, their facility to form chains and agglomerates and the degree of dispersion of the particles within the polymer [12]. Obviously, the formation of a fracture is facilitated by poor cohesion between polymer molecules and the surface of filler particles. The nature and the growth of the fractures are affected by the presence of the large particles or agglomerates, the degree of dispersion of filler particles, and attraction forces between them and polymer molecules [12].

There is bad adhesion between lignocellulose fiber and polymer because such fibers are of hydrophilic nature while polymers have hydrophobic surface. So the polymers can not be spread on PTF surface, because their contact angle is large [1,2,12]. Generally the adhesion may be valence forces (Coloumbic attraction produced by the interactions of atoms, ions, and molecules that exist within and at the surfaces of both adhesive and adherent) , interlocking action (surfaces are held together by an adhesive that has penetrated the porous surface while it is liquid, then anchored itself during solidification or both) [12-13].

The present work aims to study the influence of increasing the physical adhesion between PS and PTF surfaces by converting the hydrophilic nature of the fiber surface into a hydrophobic one by covering the PTF with PS solution. This treatment could enhance the mixing process and hence the physical and mechanical properties of PTF/PS composites.

2. Materials and Methods

The composites used in the present study were prepared using commercial polystyrene waste and local lignocellulose fibers of palm trees branches. Ground palm tree branches (PTF) fibers were dry-

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shredded into feed stock in a hammer mill. The machine was equipped with a shiff screen of opening 6 mm in diameter. After defibrating, the fibers were size class fied sieving. The fibers are soxhelt extraction with acetone for 24hrs to remove waxy substances of fibers, this extraction also removes most of the adsorbed moisture in the fiber. Therefor they left in an open air atmosphere for 24 hrs to allow solvent to evaporate at room temperaturer and at 60 °C for 24 hrs to ensure drying. Dioctyl phthalate (DOP) as a plasticizer was added to the composite samples under investgation.

The polystyrene and fibers were mixed by using laboratory mixer (*Plasti Corder 350 S, Germany* at 165 °C and rate of 25 rpm for 5 minutes). The composites were molded in a hot press at 165 °C for 5 minutes at 104 Kgm/m². The molded sheets were then immediately left to cool down to room temperature. Two types of fibers were used in the present study, the first were virgin extracted fibers (untreated) where the second were coated by polystyrene solution. Then the untreated or the treated fibers were subjected to the mechanical mixing with the appropriate amount of polystyrene.

The mechanical properties were tested using tension machine type *M-10 (Hung Ta Instrument, Taiwan)*, with sample dimensions 150x 20x 8 mm³ at rate of 15 mm/min according to the ASTM standards (D 790, 1987).

The impact toughness measurements have been carried out on the different composite samples according to ASTM standards (D-256, 1987) using a pendulum impact apparatus *PSW-4J (Gerhard Zorn Mechanische Werkstätten, Stendal, Germany)*. Nail-holding test or screw-holding test was performed using mechanical testing machine type *HT-9112 Hung-Ta Instruments Co. LTD, Taiwan*. The abrasion test was performed by using *RAUENSTEIN THURINGEN tester, Germany*. Composites water swelling test was examained according to ASTM standards (D1037-87, 100, 1987).

3. Results and Discussion

Fig (1) illustrates the applied force against bending depth for different concentration of untreated or treated PTF/polystyrene composites. It is noticed that the bending depth increases by increasing applied force up F_p , and after that force

decreases until fracture attains for the untreated fibers, Fig (1a). The fibers treated using 10% of polystyrene solution in PTF/polystyrene composites exhibits the same mentioned behavior for the different concentration of fibers, Fig (1.b).

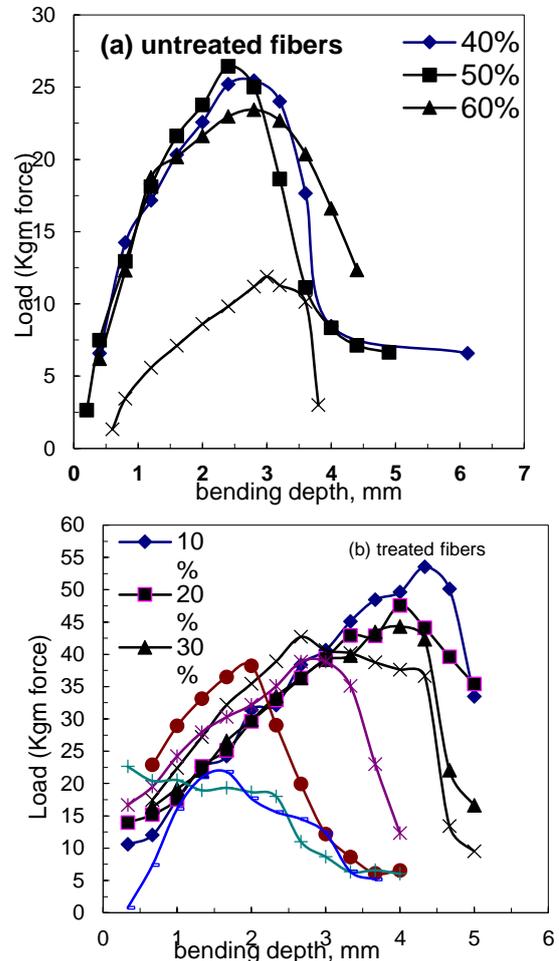


Fig (1) Applied force against bending depth (a) untreated fibers and (b) treated fibers

The peak in force-bending depth curve was shifted downward by increasing fiber concentration, and the behavior inverses beyond 60% of fiber for both treated and untreated fibers, fig (2).

One notes that by treating the fiber with polystyrene solution, Fig (2), higher values of F_p were recorded. The change of F_p against fiber concentration can be discussed on the basis of the following empirical relation:

$$F_p = F_{Po} \exp (-c/c') \dots\dots\dots(1)$$

where c' is a characteristic concentration of PTF/polystyrene composites and F_{Po} is the force

peak at $c = 0$. The values of c and F_{p0} are obtained by using the least square fitting of relation (1), they are equal to 25%, 214 kgm and 7.17%, 70 kgm for the case of the untreated and the treated fiber respectively. The value of c' is higher in the case of untreated fibers with respect to that of the treated one due to the modification of fiber surface nature.

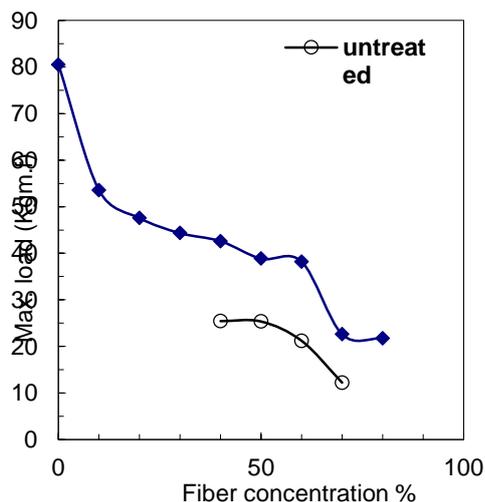


Fig (2) The Maximum applied force against fiber concentration % of untreated and treated PTF/ Polystyrene composites

The maximum strain δ_{max} was obtained ($\delta_{max} = 6 D d / l^2$, where l is the support span length, d is the depth of beam tested and D is the maximum bending depth) [14]. The δ_{max} value is plotted against fiber concentration, Fig (3).

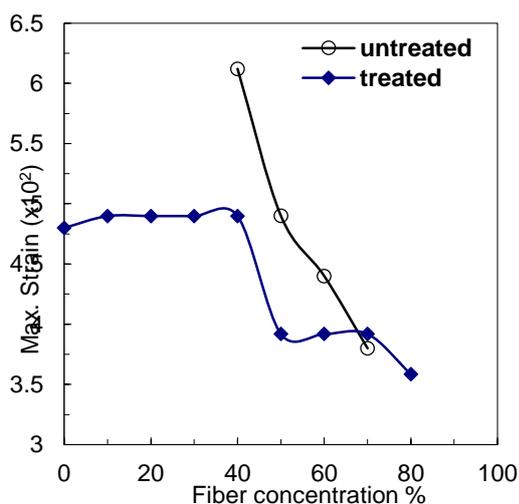


Fig (3) The Maximum Strain against fiber concentration content % of untreated and treated PTF/ Polystyrene composites

On notes that it decreases in both the untreated and treated where it shows step like behavior in the later one. The two regions in δ_{max} - C relation, are in the range (0 to 40%), and (50% to 80%) where a percolation was recorded between 40 to 50%. This behavior could be discussed as follows, at low fiber concentration, the fibers are isolated and the interfacial layers of polymer are sufficiently large, and subsequently the strain of the composite arises by the polymer itself. In addition, fibers may act as stoppers to crack growth in such composites [15]. This means that there is no change in strain values at low concentration of fibers up to 40%. Above certain concentration of fibers (critical concentration), the rigid fibers become closer to each other (the thickness of polymer layers separating fibers tends to vanish), which lower the strain because of the fiber domination in the polymer matrix.

The modulus of elasticity M_E of the PTF/polystyrene, composites has been estimated [$= P^3 m / (4 b d^3)$], where b is the width of sample tested and m is the slope of the force – bending depth in the linear elastic region before the plasticity attains [14]. The obtained values of M_E are plotted versus PTF fiber concentration, Fig (4.a). One notes that, they increase by increasing PTF concentration up to certain concentration 60% while they decreases beyond such concentration. In addition, M_E increases, in genral, by treating the fibers by polystyrene solution compare with the untreated ones. This is expected because of the increase of the polymer - fiber adhesion improvement, besides the reduction of the composite matrix free volume [12]. The concentration dependence of M_E can be explained by the following empirical relation;

$$M_E = M_{E0} \exp(\alpha C) \dots\dots\dots(2)$$

where α is a fitting parameter and M_{E0} is the modulus of elasticity at $C= 0$ of fibers concentration. The value of M_{E0} has been estimated using the least squar fitting of relation (2), it is equal to 1.78 G.Pa which is about 77% of the recorded value of polystyrene unloaded matrix (2.3 G.Pa) [16]. This can be attributed to the polymer matrix porosity. The highest value of M_E obtained is equal to 3.45 GPa at 60% of treated fiber in PTF/polystyrene composites, it is in agreement with the published work [17].

The absorbed energy E_a ($= a / lbd$, where a is the area under the curve of F-bending depth relation [14]) obtained is plotted against PTF fiber concentration, for the untreated and treated fibers composites Fig (4.b). It is noticed that the energy absorbed decreases by increasing fiber concentration, while E_a shifts up by the fiber treatment which reflects the improvement of the sample rigidity.

The Modulus of rupture M_R , which is defined as the maximum stress required to arise rupture for the composite sample ($= 3F_p l / 2bd^2$), [14] The values of M_R are plotted against fiber concentration for the untreated and treated fiber in PTF/polystyrene composites, Fig (4-c). The results show that M_R values in PTF/polystyrene composites decrease by increasing fiber concentration for both the untreated and treated fiber composites whereas their values are, in general, high in the case of the treated fibers. The values of $M_R = 31.8$ MPa at 60% of fibers is in agreement with the published data [17].

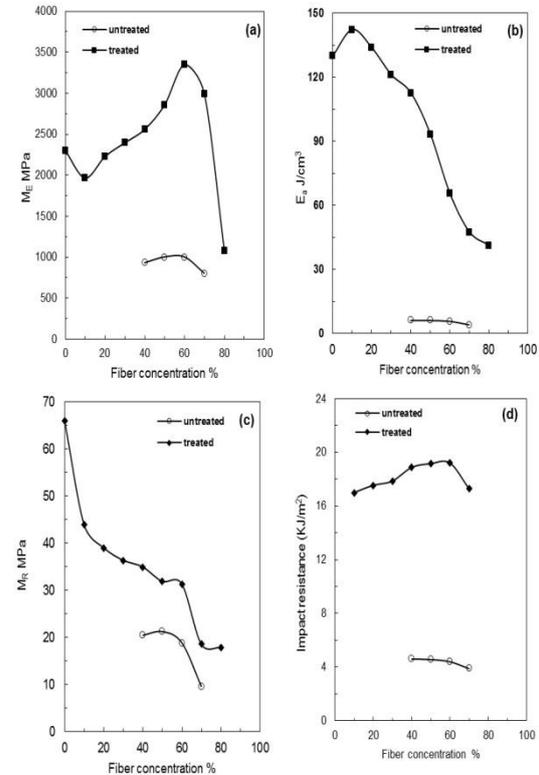
The impact resistance of the PTF/polystyrene composites has been obtained, ($I_R = A_n / b d$, where A_n is absorbed impact energy [18]). Fig(4.d) illustrates the impact resistance of the treated and untreated fibers in PTF/polystyrene composites versus the fiber concentration. One notes that the impact resistance decreases by increasing fiber concentration, which shows a maximum at 60%, and reaches 19.21 KJ/m² for the case of the treated one.

Subsequently the influence of fiber size on the mechanical properties of the samples has been studied. Fig (5) illustrates the force-bending depth relation for different size of treated fibers at the optimum fiber concentration, (60%), in PTF/polystyrene composites.

It is noticed that the maximum strain δ_{max} and F_p increase by increasing fiber size in treated PTF/polystyrene composites. In addition, the values of M_E , M_R and I_R are high for the case of the medium fiber sizes and are equal to 3345 MPa, 26.18 MPa and 18.75 KJ/m² respectively. This can be discussed as follows; in the case of smaller fibers (< 0.5mm), they fill the whole free volumes of the polymer matrix.

This affects negatively the sliding of polymer chains on each other, with smaller strain. For the larger fiber sizes, the partial free volume of polymer

matrix still unoccupied, and some voids are created by the larger fibers packing leading to larger strain. Moreover, by increasing the fibers size the reinforcement of polystyrene increases and hence the moduli of elasticities also increase.



Fig(4) The Modulus of elasticity(a), the absorbed energy to break (b), Modulus of rupture (c) and the Impact resistance (d) against untreated and treated fiber concentration in PTF/Polystyrene composites .

When the fiber become larger than a certain size, the polymer matrix is not capable to enclose the large fibers, this may create some additional voids in the polymer composite matrix, and leads to poor adhesion between the polymer and the fibers, so the modulus of elasticity decreases. By using wide distribution of fibers, the smaller fiber fills the voids which lead to some polymer rigidity while the larger fibers connect the polymer portions and lead to reinforcement of polymer composites matrix.

Fig (6) illustrate the morphology of untrated or treated fiber with polystyrene soluotion. It is clear that the surface of the untreated fiber is characterized by a pronouncing roughness whereas the fibers surface modification using polystyrene solution reduces such roughness.

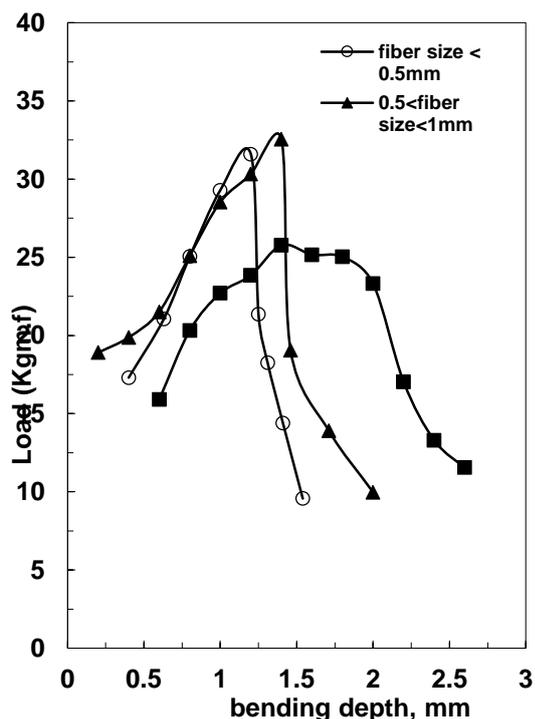


Fig (5) The applied force against bending depth for different fiber size of treated PTF/ Polystyrene composite at 60% of fiber content

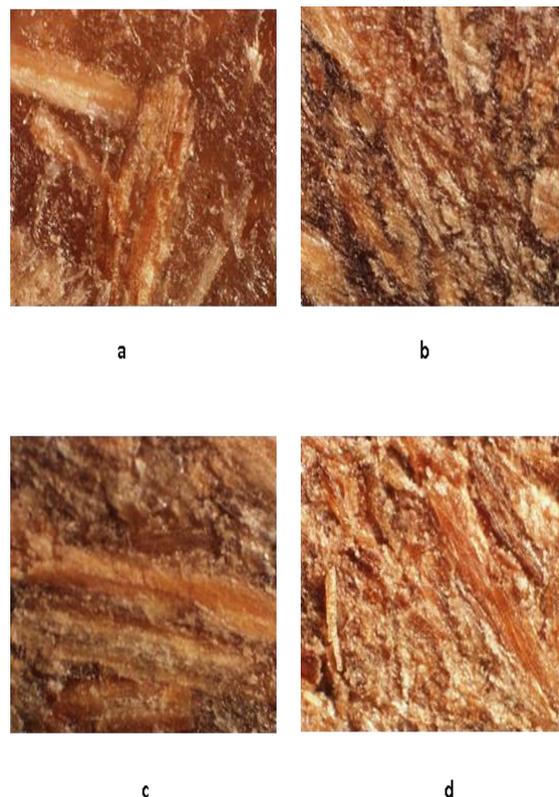


Fig (7) The surface morphology of treated PTF/Polystyrene composites for different fiber concentrations a=20%; b=40%; c=60%; d=80%. 32 x

In addition the treated fibers composite clearly illustrate less voids and cracks compared to the untreated fibers composite.

Smooth and screw nail withdrawal test,[19] were carried out for PTF/polystyrene composites of different fiber concentrations. Fig (8) illustrates the force required to pull out the nails from the composites against the fiber concentration for untreated and treated PTF/polystyrene composites. One notes that the force increases by increasing fiber concentration until fiber concentration 50%, then it decreases again by increasing fiber concentration. This behavior can be discussed as follows; at lower concentration of fiber the composites have little rigidity and subsequently lower nails holding. By increasing the fiber concentration the rigidity of the composites increases, which leads to higher pull out force for nails, up to certain concentration at which the rigidity decreases again then the required force to pull out the nails from the composites decreases (the domination of fiber aggregation behavior in PTF/polystyrene composites).

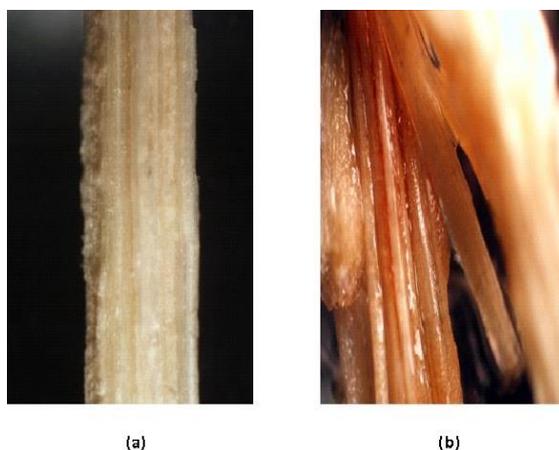


Fig (6) The surface morphology of (a) untreated fiber (b) treated fiber. 32x

It is clear also that fibers aggregation increase in the case of the untreated fibers where they are dispersed and isolated from each other as fibres have been treated by polystyrene solution in PTF/polystyrene composite, Fig (7).

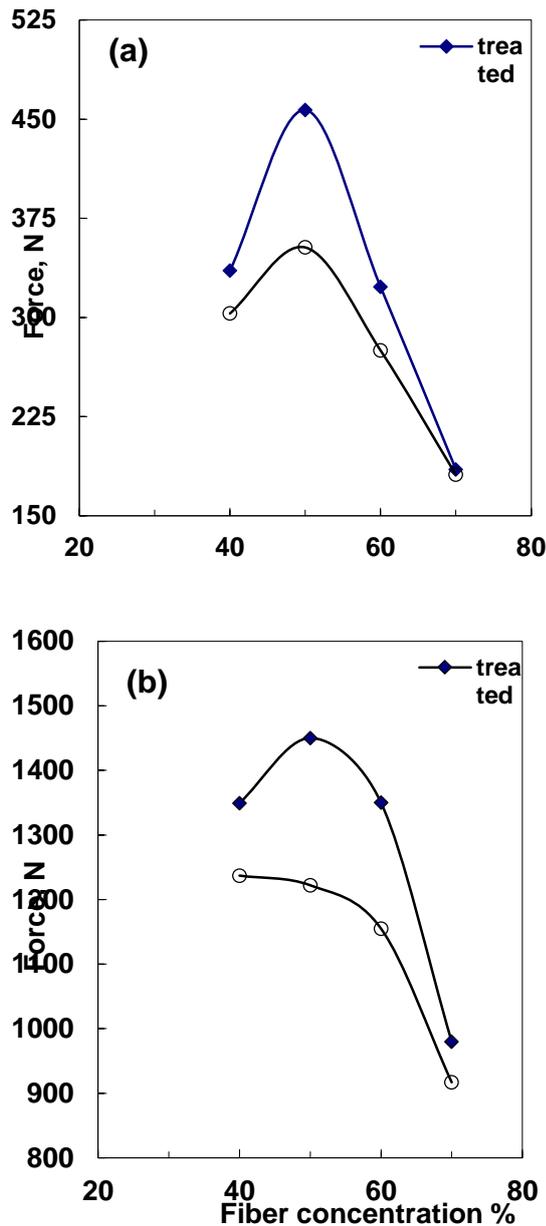


Fig (8) The tensile force for nail withdrawal against fiber concentration for treated and untreated fiber PTF/Polystyrene composites (a) smooth nail (b) screw nail

It is clear that a similar behavior was obtained for the treated fibers, It was shifted upward by the mentioned treatment. The force required to pull out the screw nails =14.500 KN is larger than that for the case of smooth nails 0.437 KN, at the optimum fiber concentration 60%, because of their great binding due to the nails larger surface roughness.

The surface abrasion of PTF/polystyrene composites for different concentration of fiber was estimated according to ASTM (D 1034-98)[20].

Fig (9) illustrates the percentage sample weight loss against the fiber concentration, one notes that the abrasion loss increases by increasing fiber concentration.

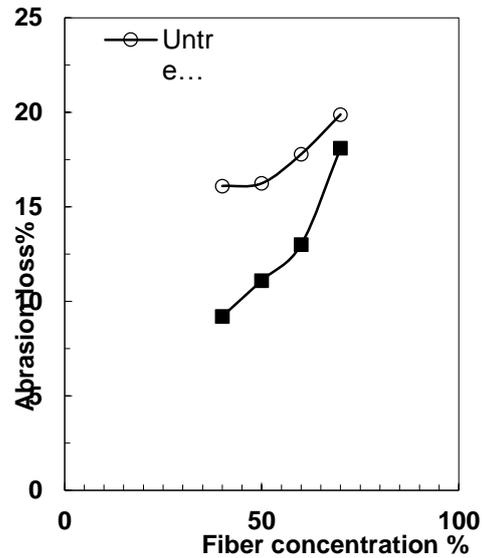


Fig (9) The Abrasion percent of untreated and treated PTF/Polystyrene composite against fiber concentration

This behavior is expected; since the polymer itself resists the abrasion than the rigid cellulose fibers. The treated fiber composites are more abrasion resistive than the untreated ones. This reflects the surface modification of the cellulose fibers surfaces. The change in composite abrasion by such surface modification can be attributed to: (i) the decrease of fiber aggregation in PTF/polystyrene composites, (ii) the decrease of free volume (voids and cracks), (iii) the remarkable increase of adhesion between fibers and polystyrene.

Water absorption of both untreated and treated fibers PTF/polystyrene composites was measured after 24 hrs of soaking [21], Fig (10).

It is noted that the water absorption of the composites increases by increasing fiber concentration. In addition, the water absorption reduces by fiber treatment compared to the untreated ones, because polystyrene solution fills the pores of the fibers which protects the fiber from water penetration as well as it lowers the free

volume in composites as a result of voids concentration reduction. It is also clear that water absorption in the case of 60% of fiber composite is equal to 4% which is low compared to the natural wood 100% for the same period of soaking at the same atmospheric conditions.

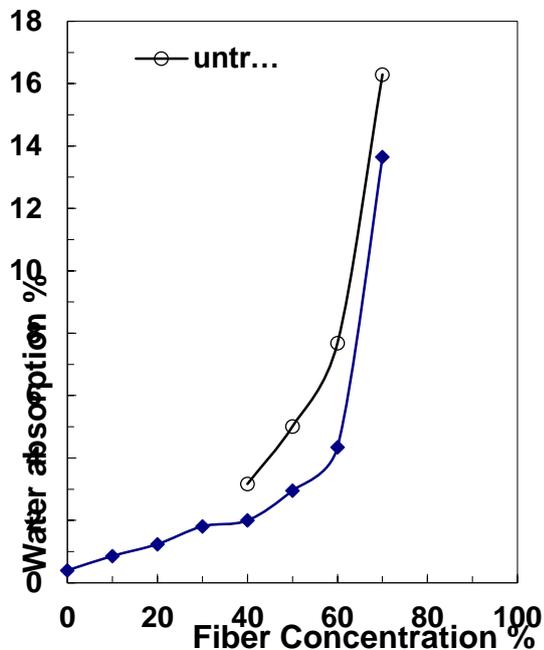


Fig (10) The Water absorption against fiber concentration of untreated and treated PTF/Polystyrene composites

4. Conclusion

The physical adhesion treatment of palm trees fibers with polystyrene solution enhanced the mechanical and the physical properties of the PTF/PS composites. The optimum fiber concentration was found to be 60 wt.%. The MOE of PTF/PS composites using treated fiber was found to 3 times higher than untreated fibers. Water absorption and abrasion resistance have been improved PTF/PS composites by using the treated fibers.

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