The influence of palm fronds ash (PA) on some physical properties of polypropylene (PP).

Nadhim A. Abdullah[a]*, [a] Department of Material Science, Polymer Research Centre, University of Basrah, Basrah, Iraq.
* Corresponding author: *nadhim.abdullah@uobasrah.edu.iq*

Ahmed J. Mohammed[a] [a] Department of Material Science, Polymer Research Centre, University of Basrah, Basrah, Iraq.

Ziyad T. Almalki[b] [b] Department of Chemistry and Polymer Technology, Polymer Research Center, University of Basrah, Basrah, Iraq.

Ahmad J.H. Almaliky[c] [c]Department of physics, College of Education for Pure Sciences, University of Basrah, Basrah, Iraq.

Ibrahim K. Ibrahim[c]. [c]Department of physics, College of Education for Pure Sciences, University of Basrah, Basrah, Iraq.

ABSTRACT

The base material was polypropylene (PP), and the filler was palm frond ash (PFA) in weight percentages of(1%, 2%, 3%, 4%, 5%, 6%, 7.5%, and 10%), with an equivalent particle size of (75 µm). For determining the mechanical properties of the mixes (the proportionate limit), measure a variety of variables of the new material (the base material and the filler addition), including stress at yield, stress at break, elongation, Young's modules, and the limit of proportion to the polymer with fillers. The practical outcomes of this study demonstrated that adding palm frond ash to the polymer decreases the gaps between the polymeric chains, reflecting the polymer's high pressure tolerance, that the degree of homogeneity between the polymer and fillings is high, and that increasing the percentage of additives increases the character of the polymer. The results indicated that the tensile strength behavior is effective at a percentage (1%) of the addition, then declines with a very slight percentage rise in the amount of the additive. The hardness of the manufactured samples was at a percentage (1%). The Young's coefficient is low with its percentage added at 2% because palm frond ash as filler impacts the properties of polypropylene; this demonstrates the flexibility of the polymer grafted with palm frond ash and the expansion of the polymer's range of applications.

Keywords: Polypropylene, palm frond ash, thermal conductivity, mechanical properties, compression, Young modulus.

Introduction

Fillers are organic or inorganic components that are incorporated into a polymer to increase its volume, decrease its cost (in this case, inert fillers), or enhance its mechanical and thermal properties (active fillers). Solid materials, often known as fillers, are added to polymers to enhance their qualities and reduce costs, but they work the opposite way as plasticizers in that they reduce the ductility of the polymer [1-2]. Fillers are used below the glass transition to reduce fragility and play a significant effect in the strength of elastic materials like rubber. The amount of filler for the material, which can be either organic (such as nylon and rayon) or inorganic (such as glass and carbon), is particularly essential since these fillers are used to lower the cost of the

material and to improve the shape and size of polymeric products. A number of factors, including the fillers' particle size, organic status, concentration, kind of interaction with the polymer matrix, and chemical makeup, affect the physical properties of polymeric composites [3]. Prior studies devoted a lot of space to polymer composite materials reinforced with different kinds of glass, carbon, and metal fibers because of their many applications, but they paid much less attention to polymer composite materials reinforced with particles than they did to fiber-reinforced materials. The base (matrix) of composite materials is composed of ductile, high-strength materials like polymers, and the reinforcing phase is composed of fibers, powder, and scales from solid materials such polymers, ceramics, and metals [4]. Many researchers have looked at the mechanical characteristics of some polymeric materials and their additions. A team of researchers [5] examined the mechanical characteristics of a polymer containing potassium alum powder, and the actual outcomes showed that the material's strength behaved as predicted. The ratio (10%) produces the most effective stress at break (MPa 6.65), whereas the ratio (20%) yields the highest Young's modulus (96.05 MPa). At a weight ratio of 10%, the highest proportional limit value was (163.6 N), while the highest point of stress was (10.95 N/mm2). A practical examination was conducted by the researcher [6] and his team to determine the mechanical characteristics of polymer composites made of fiberglass reinforced with coal ash. According to the data, coal ash has the highest tensile strength (20%) among all the varied weight ratios, and filler weight has the highest maximum bending strength (16%). According to the practical results of the researcher's [7] study of the mechanical properties of polymer containing oyster shell powder, the maximum Young modulus, estimated to be 140.5 MPa at the ratio (15%), as well as the value at the percentage (10%), the maximum elongation was (39.4%), and the highest value of the (proportional limit) was (143 N) for the weight ratio (5%) The experiment was done by the researcher and his colleagues [8] in order to determine the mechanical and physical characteristics of a fly ash-epoxy resin composite. According to experimental results, the highest tensile value was attained at a weight ratio of 30%, while the maximum hardness was at a weight ratio of 40%. The researcher [9] looked into the process of enhancing some mechanical properties of polymers with fly ash and discovered that using fly ash particles as small as (14 m), they were able to produce results showing an increase in tensile strength of up to (22% and a decrease in elongation with increased concentration of fly ash. Due to its many advantages over other thermoplastics, including its low density, flexibility, recyclability, chemical and corrosive resistance, ease of processing, invariance dimensions, and low cost, polypropylene (PP) has been promoted as the perfect material for a variety of industrial applications and can be processed in a variety of ways right from the start [10]. More focus has been placed on polymer-based composite materials' excellent heat conductivity. As a result of these benefits, thermally conductive polymer composites have a good chance of replacing metal portions in cutting-edge applications such electric motors, power electronics, generating machines, microelectronics, and others [11]. This research aims to build polymer composites of polypropylene (PP) and palm frond ash as a solid filler in a variety of concentrations, and to examine the thermal-mechanical characteristics of those composites. Investigated were the effects of employing eco-friendly palm frond ash as filler on the mechanical and thermal characteristics of polypropylene (PP). The advantages of waste recycling are reflected in the environmentally friendly filler materials. Filler influences the morphology and makes the material more force. Additionally, the use of palm frond combustion ash in polypropylene (PP) material technology complies.

The experimental.

-Base material and fillers.

In this investigation, a thermoplastic elastomer called Polypropylene (PP), which is produced

chemically through propylene polymerization, was used. It is a polyolefin that is a member of the main polyolefin family. Polypropylene can be used to create a variety of plastic products that call for hardness, flexibility, light weight, and heat resistance. In order to create a flexible ethylene-propylene copolymer, it can also be copolymerized with ethylene. [12] In this investigation, polypropylene produced by Songhan Plastic Technology Co., Ltd. (SABIC, PP 500P, and homopolymer) was employed; Table (1) lists some of its features.

Table (1): Some properties of polypropylene used in the research

Density Melt Flow	Processing Temperatur e	Density	Hardness, Rockwell R	Izod Impact, Notched
3.0 g/10 min	235 - 250 °C	0.905 g/cm^3	102	0.250 J/cm
Tensile Strength, Yield	Elongation at Yield	Flexural Modulus, 1% Secant	Deflection Temperature at 0.46 MPa (66 psi)	Vicat Softening Point
35.0 MPa	10 %	1500 MPa	100 °C	152 °C

palm frond ash (PFA) from Basrah, Iraq, As part of the category of natural fillers, this substance contains hardness, strength, and a variety of components, such as proteins and others, which are among the characteristics that set it apart from other fillers such as polymer fillers [13]. It was obtained by completely burning dry palm fronds in the air, and after the powder was handled with an Allen-Bradley Sonic Sifter Model L3P wire sieve, given by ATM Corp. of America, it was ultrafinely ground to a particle size of less than or equal to 75 μm. A picture of the collected palm fronds and ash is shown in Figure 1. To identify the components of palm ash, we conducted an X-ray diffraction (XRD) examination using the x'pert software (XRD-x'pert). Philips-Holland-Kashan University).

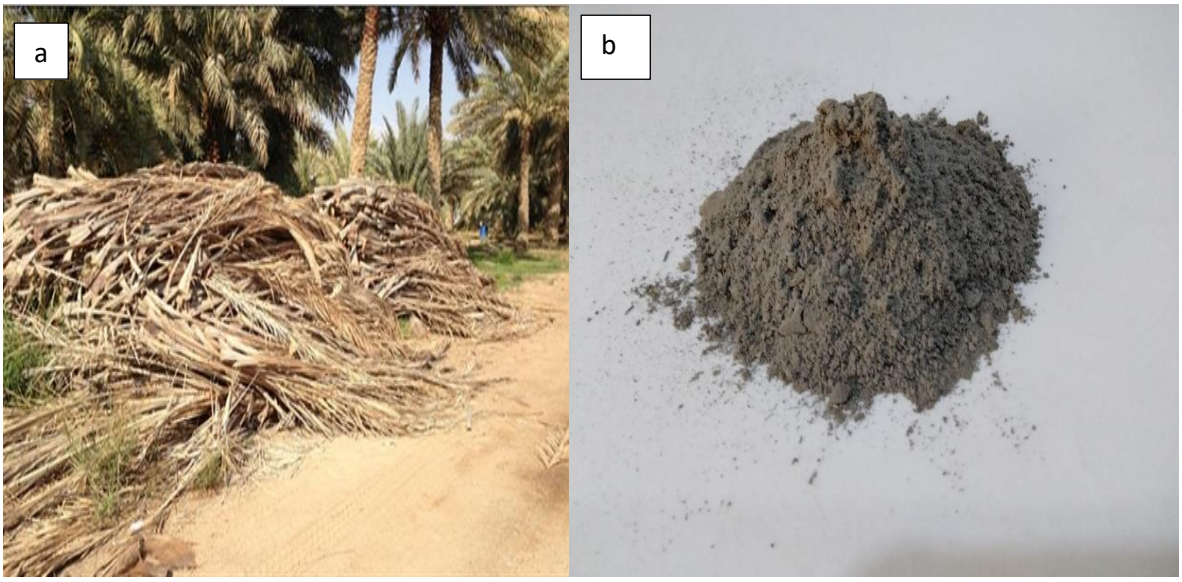


Figure (1): A photograph showing :(a)palm fronds, (b) Palm fronds ash (PA).

-Preparation and Test of Samples.

In order to manufacture composites, we used a mixer device, the Haake Rheocord Torque Rheometer (American business Haake), to combine polypropylene and palm frond ash (PA) at the desired weight percentages in order to create composite materials. The following are this device's key characteristics:

1. The largest amount of polymeric compounds that can be mixed with it ranges from 45 to 60) gm, depending on the density of the polymer.

2. Controlling the temperature so that it remains constant during the mixing process.
3. The device's ability to quickly heat up from laboratory temperature to a degree (500 ^{o}C) within (15 minutes) and vice versa for its ability to cool.
4. The speed of the mixer rotary motor can be controlled depending on the cutting speed (shear rate). Where the mixture was mixed at a temperature of 160 ^{o}C by adding the specific weight ratios, and then the mixture was rotated for about 50 revolutions per minute for a period of 10 minutes, and after the mixing process, the mixture was pressed using the hydraulic piston.

The hydraulic press has used a device of the type (PHI automatic compression press, USA) with the following specifications: range of temperature = 0–400 C; range of compression = 0–60 ton; per heat time = 0–12 min; medium force time = 0–12 min; material cure timer = 0–36 min; and cooling timer = 0–36 min. Where this piston has a cooling system and two heating systems and is operated at temperature (175 ^{o}C) and pressure (5 tan) for 3 minutes, it is then raised to 15 tan for 3 minutes (10 minutes). Following the pressing process, the samples with dimensions (20X20) cm^2 are pulled to the cutting device, where the samples are cut using the device (Automatic Hollow Die punch-Code 6050/000) supplied by the American company (CEAST), where this device cuts the model according to the cutting models that are present in it and the examination to be performed. Figure (2) displays an image of the measurements of the tensile strength test model for samples of thickness measurements (2.4 mm) [15].

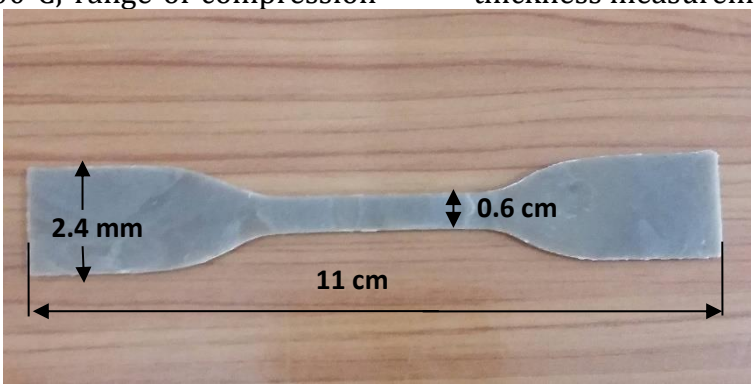


Figure (2) shows the measurements of the tensile strength test sample

The thermal conductivity (K) measurement has been done by the P.A. Hilton H940 Heat Conduction Unit, and K has been calculated using Fourier's law. The equation is given as follows: [10–11, 14].
Where K is thermal conductivity (W/m.°K),
q; heat energy (W)
A: area of the test specimen (m^2).
x; thickness of the test specimen (m).
T: temperature (°K).
The composite samples were examined using the tensile device of German origin, which measured tensile strength and strain, and the models were assessed according to the requirements ASTMD638,[15], since the stress-strain curves for all models were recorded and the tensile strength (Q) was computed using Equation (2) [16].
Q = F / A (N/mm^2)..... (2)
Where:
F = cutting force (N), A = model cross-sectional area (mm^2).
The Young modules of the samples were determined using the stress-strain curves and the following formula:
Young modules (Y) = stress/strain... (3)

Figure (3) A photograph showing a device for measuring of mechanical properties.

Results and Discussion.

1- XRD analysis of Palm Ash:

X-ray diffraction (XRD) analysis of powdered palm ash was performed at room temperature with the use of x'pert software to detect and match the peaks in order to characterize the components of palm ash. Table (2) contains the data derived from the XRD peaks, and Figure (4) depicts the XRD pattern of PA powder. Table 3 displays the outcomes of the search and match operation performed using the x'pert software. This table shows the anticipated components of palm ash together with their weight percentages. [17].

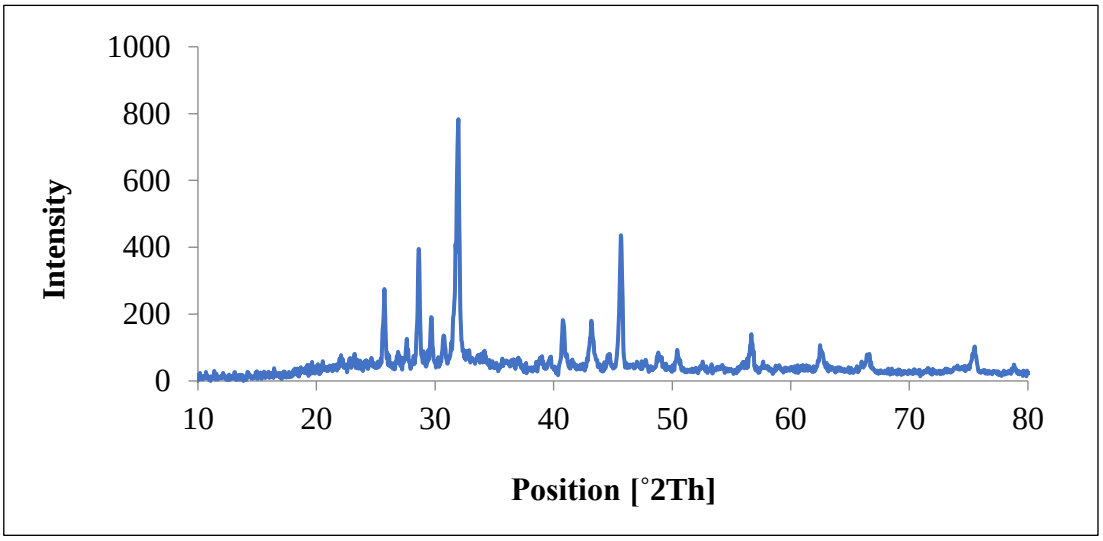


Figure (4) shows the XRD pattern of PA powder

Table (2) shows the data which obtained from XRD peaks

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-spacing	Rel. Int. [%]
13.6788	9.68	0.0984	6.47374	1.37
14.2684	14.89	0.2952	6.20754	2.10
17.2400	13.67	0.1476	5.14367	1.93
22.0257	33.12	0.2952	4.03570	4.68
22.7900	29.11	0.1476	3.90206	4.11
23.1729	35.40	0.1476	3.83844	5.00
25.7327	229.73	0.1968	3.46212	32.47
26.8651	27.80	0.2952	3.31870	3.93
27.6255	77.08	0.1476	3.22907	10.89
28.6373	340.65	0.1968	3.11723	48.15
29.6805	139.34	0.1476	3.01001	19.69
30.7550	81.12	0.2460	2.90725	11.47
31.9480	707.50	0.2460	2.80136	100.00
39.6569	28.82	0.2952	2.27278	4.07
40.8078	141.67	0.1968	2.21130	20.02
43.1826	142.07	0.2460	2.09503	20.08
44.6328	36.60	0.2460	2.03027	5.17
45.7116	370.36	0.2460	1.98484	52.35
48.8940	36.22	0.3936	1.86283	5.12
50.4575	52.12	0.1968	1.80872	7.37
56.6742	109.12	0.1968	1.62419	15.42
62.5091	56.69	0.2460	1.48588	8.01
66.6142	52.86	0.3444	1.40393	7.47
75.5213	74.50	0.3444	1.25895	10.53
78.8525	20.31	0.3600	1.21291	2.87

Table (3) the expected elements that's constituted PA.

Ref. Code	Compound Name	Chemical Formula	Score	Scale Factor
00-027-1402	Silicon, syn	Si	19	0.143
00-038-1479	green cinnabar	Cr_2O_3	Unmatched Strong	0.026
01-075-0134	Uranium Oxide	UO_2	16	0.0034
00-010-0173	alumina	Al_2O_3	21	0.101
00-006-0329	Praseodymium Oxide	$PrO_{1.83}$	16	0.015
00-024-0072	Hematite	Fe_2O_3	Unmatched Strong	0.182
00-033-0664	burnt ochre	Fe_2O_3	Unmatched Strong	0.125
01-077-2041	Sodium Erbium Fluoride	$NaErF_4$	14	0.011
00-035-0816	Fluorite, syn	CaF_2	12	0.005
00-006-	Chromium, syn	Cr	9	0.000

0694				
01-073-1667	Bornite	Cu_5FeS_4	10	0.065
00-005-0586	Calcite, syn	$CaCO_3$	19	0.049
00-033-1161	silica	SiO_2	10	0.014
00-046-1045	Quartz, syn	SiO_2	9	0.015

2-Thermal properties:

The pure polymers were known as good thermally insulators, with a thermal conductivity in the range of (0.1–0.5) W/(m K), which can be increased significantly by using carbonic, metallic, or ceramic particles as a filler to make composite materials. These composite properties depend on some properties of the filler, such as the particle size and shape, so that the addition concentration and selected processing method and their interactions with the polymer [14].

The objective of studying the thermal properties is to identify the thermal behavior of the prepared composites. The DSC was introduced to investigate the effect of the additive on the thermal stability of the polymer through changes in the melt temperature (Tm) of the composites and thus determine the appropriate role for them in the applied fields [18].

The DSC testing of the prepared pure and filled polypropylene was determined by using a DSC-60 Shimadzu (Japan). Appropriate amounts of samples (5 mg) were sealed in aluminum pans and heated from 25 to 300°C at a (10 ^{o}C/min) heating rate within a nitrogen atmosphere.

Generally, the obtained results shown in figure (5) and table (4) illustrate that increasing the percentage from (1% to 10%) of the additive PA increases the Tm, thus increasing the thermal stability of the polymer from (Tm = 124.78 °C) for pure polymer to (Tm =145.24°C) for polymer with 10 % PA. This can expand the range of use of the polymer [19].

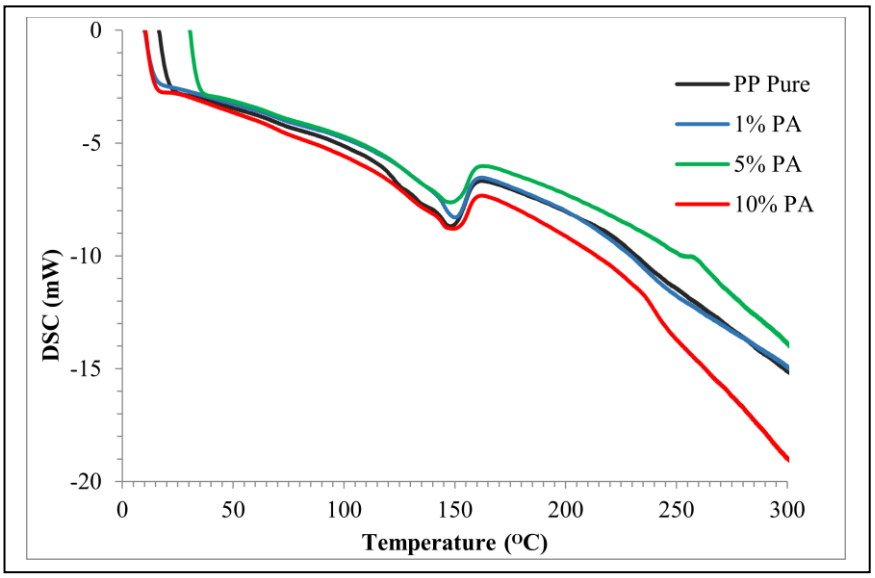
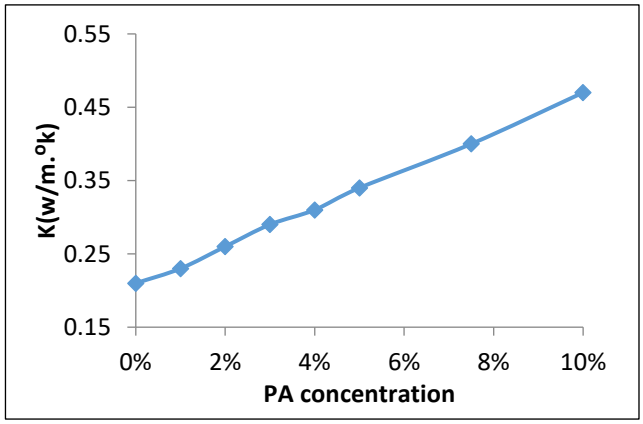


Figure (5) DSC measurement corves of polypropylene composites.

Table (4): Brief data of DSC measurement of polypropylene composites.

Sample	T_i / °C	T_{max} (T_m)/°C	T_f / °C	ΔT_f / J/g
PP pure	124.78	147.89	157.71	-17.22
1 % PA	126.91	148.03	157.88	-24.84
5 % PA	145.24	149.31	158.43	-16.18
10 % PA	143.06	150.2	158.14	-13.96

The thermal conductivity units (w/m.°k) have been calculated using the equation (1). The increase in thermal conductivity (K) of PP after adding PFA is clearly visible in figure (6) (and table). This is due to the fact that the ash has a higher thermal conductivity than the thermal conductivity of the base polymeric material, so the increase in the thermal conductivity coefficient is proportional to the amount of addition. In addition to containing ash on conductive metal structures, which in turn contain moving electrons with high thermal conductivity, polymers contain localized electrons, allowing heat to be carried in them solely by vibrating the lattice. [20].



PA ratio	K (w/m.°k)
0%	0.21
%1	0.23
%2	0.26
%3	0.29
%4	0.31
%5	0.34
7.5%	0.40
10%	0.47

Figure (6): Illustrate the thermal conductivity of PP/PFA composites.

3-Mechanical properties:

Figure (7) displays the stress-strain curves for PP polymer that has been grafted by weight in the following percentages: 0%, 1%, 2%, 3%, 4%, 5%, 7.5%, and 10%. The first part of the stress-strain curve represents Hooke's law (a straight line that represents the elasticity of the model) (linear region), and then a small curvature occurs through which we can obtain the sample modulus of elasticity, and this part of the curve represents flexible behavior (yield region). When the force applied to the samples is removed, the energy expended is stored in the form of elastic energy, and when the samples exceed this part of the curve, it either weakens at a point where the polymer is flexible and thus reduces the stress applied to it, or it ruptures when the polymer is not flexible (brittle), and the maximum applied force that the samples can bear before it weakens is called the tensile strength (the end of the elastic behavior in the polymer). We notice a gradual increase in the applied stress after the region of weakness due to the arrangement of the polymer samples (polymer chains) in the direction of the prepared sample's withdrawal axis, thus increasing the force applied to the model. By increasing this force, the model reaches the stage of rupture (break region). As we can see, the tensile strength (hardness) has a value of (Mpa 34.8) at the ratio (1%), and the highest value of the maximum elongation (elasticity) was (11.5%) at the ratio (the stress-strain curve represents Hooke's law (a straight line that represents the elasticity of the model) (linear region), and then a small curvature occurs through which we can obtain the sample modulus of elasticity, and this part of the curve represents flexible behavior (yield region). When the force applied to the samples is removed, the energy expended is stored in the form of elastic energy, and when the samples exceed this part of the curve, it either weakens at a point where the polymer is flexible and thus reduces the stress applied to it, or it ruptures when the polymer is not flexible (brittle), and the maximum applied force that the samples can bear before it weakens is called the tensile strength (the end of the elastic behavior in the polymer). We notice a gradual increase in the applied stress after the region of weakness due to the arrangement of the polymer samples (polymer chains) in the direction of the prepared sample's withdrawal axis, thus increasing the force applied to the model. By increasing this force, the model reaches the stage of rupture (break region). As we can see, the tensile strength (hardness) has a value of (Mpa 34.8) at the ratio (1%), and the highest value of the maximum elongation (elasticity) was (11.5%) at the ratio (2%). When filler percentages are increased, it becomes less flexible and harder, especially at higher percentages (4%)[21].

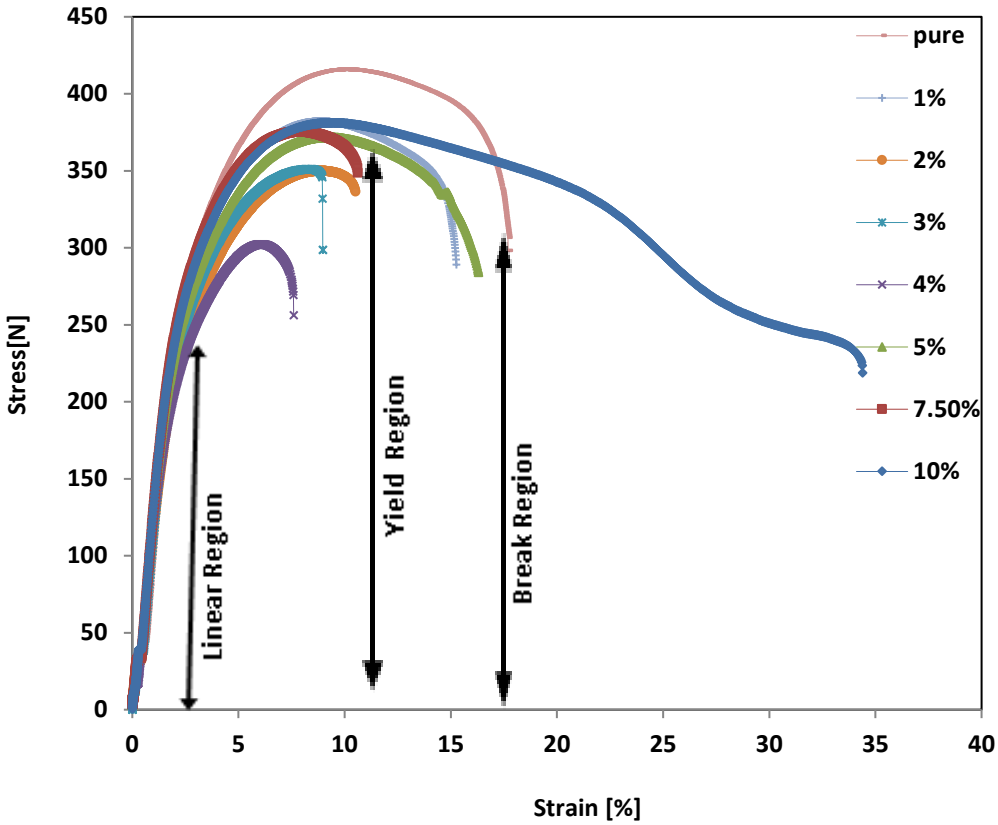


Figure (7) relationship between stress-strain curves of PP/PFA composites.

The proportion of elongation in the model and the additive's concentration are correlated, as shown in Figure (8). Elongation of the polymer drops from 10% at 0% of the pure polymer to 8.9% at 1% of the pure polymer, suggesting that the polymer is less flexible at this level. As a result, the ash from palm fronds aids in filling the crevices between the polymer's main chains, which hampers and restricts the chains' mobility. The behavior then decreases as the percentage of additive concentration increases, to achieve the smallest value of maxima. It then increases when the concentration of the additive increases at the ratio (2%), and the polymer is highly elastic and has low hardness at this ratio because the polymeric chains are unrestricted, meaning they are free to move, possibly as a result of the mixture's heterogeneity[23]..

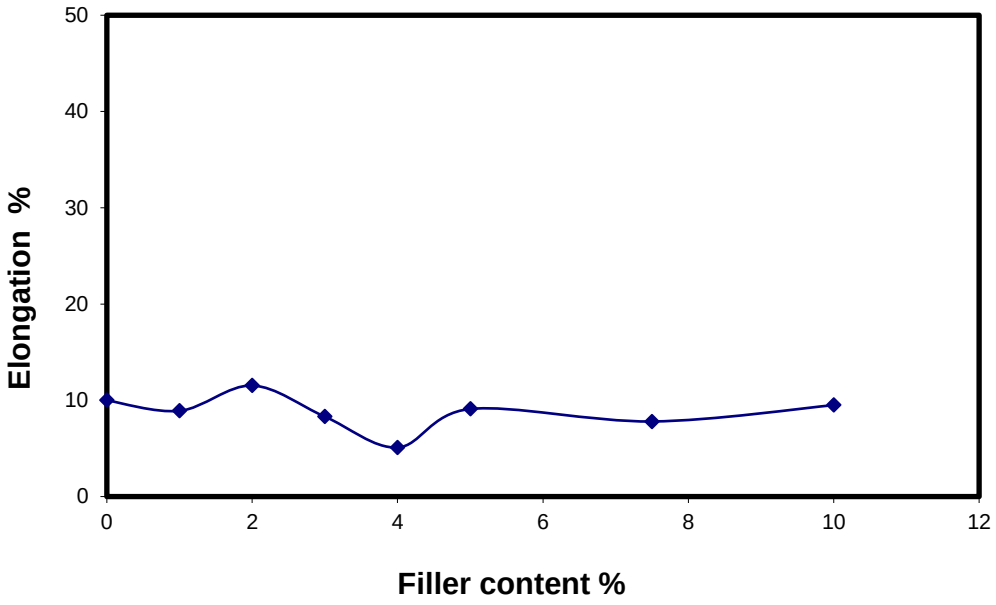


Figure (8) relationship between elongations of PP/PFA composites

Figure 9 indicate the influence of palm frond ash powder on the Young modulus, which is the ratio of stress to elongation for solid materials only. The Young modulus is shown in the figure to decrease at weight ratios of 0% and (3.4 MPa), increase to reach its highest value at ratios of 4% and (5.69 MPa), and then decrease to its lowest value at ratios of 10% and (3.6 MPa). This behavior of the mixture (polymer with the addition of palm frond ash powder) shows that the ash of palm frond ash powder affects the polymer's ability to elongate. Although the models were mixed in identical settings in this field, the heterogeneity of the model may be to blame for the decline in Young modulus at the ratio (10%) [23].

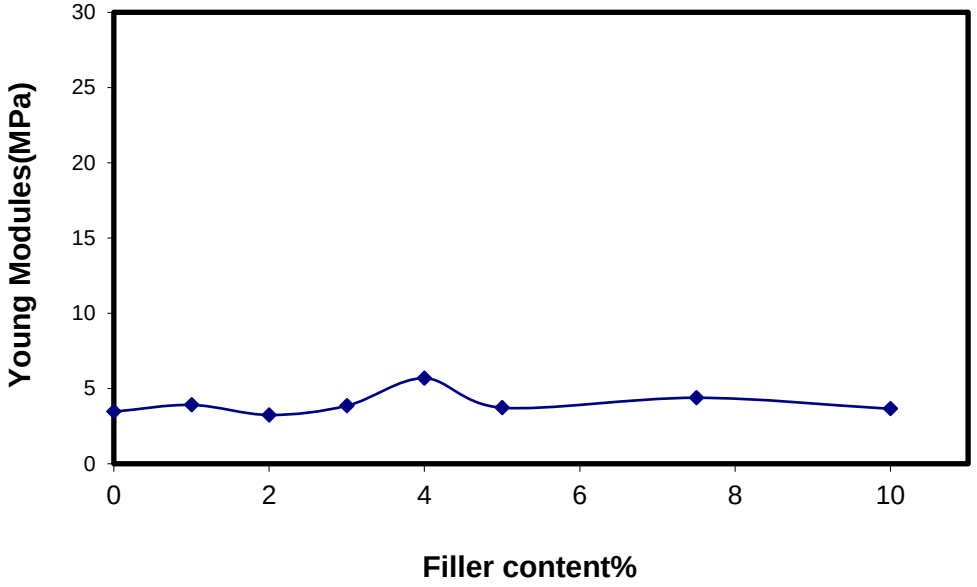


Figure (9) relationship between Young modulus of PP/PFA composites.

Figures 10 and 11 show, respectively, the relationship between the weight ratios of the additive to the polymer and tensile strength (max stress and tensile strength at break).

Figures below show, which the strength behavior is highly influenced by the additive's percentage (2%), and then decreases when the filler is increased. In other words, palm frond ash powder works by making the polymer less hard, which causes the polymeric chains to become unbound and increase in flexibility. The influence of stress during the break is initially minimal at (1%). Then, as the additive concentration increases, it rises until it reaches its maximum value (35.1 MPa) at the percentage (2%) and then falls until it reaches 19 MPa at the percentage (10%). When the concentration ratios of the additive are increased, especially between 7.5% and 10%, the percentages of the additive show that the ash of palm frond powder enhances the hardness property by virtue of the homogeneous distribution of the solid nature [21].

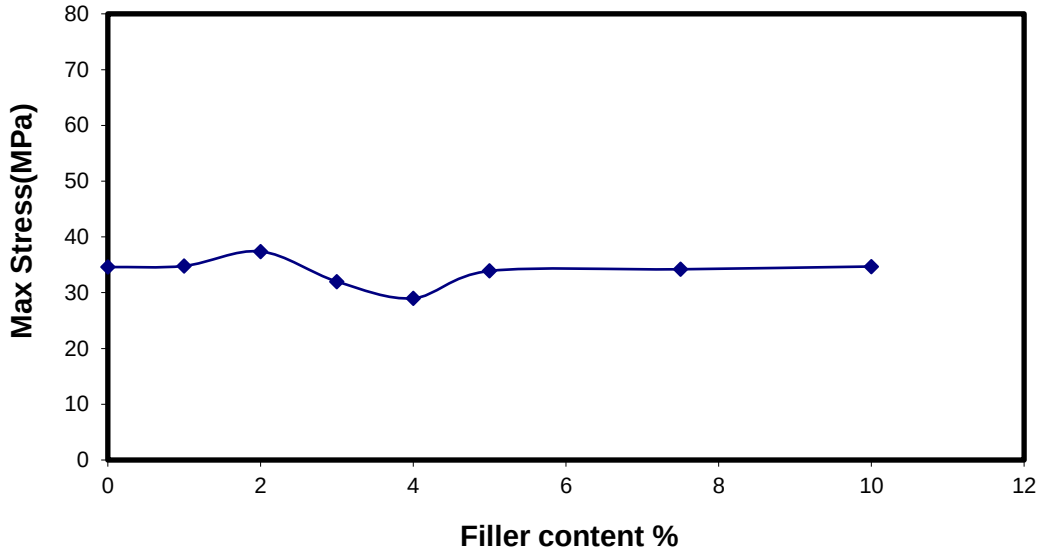


Figure (10) relationship between Max Stress of PP/PFA composites.

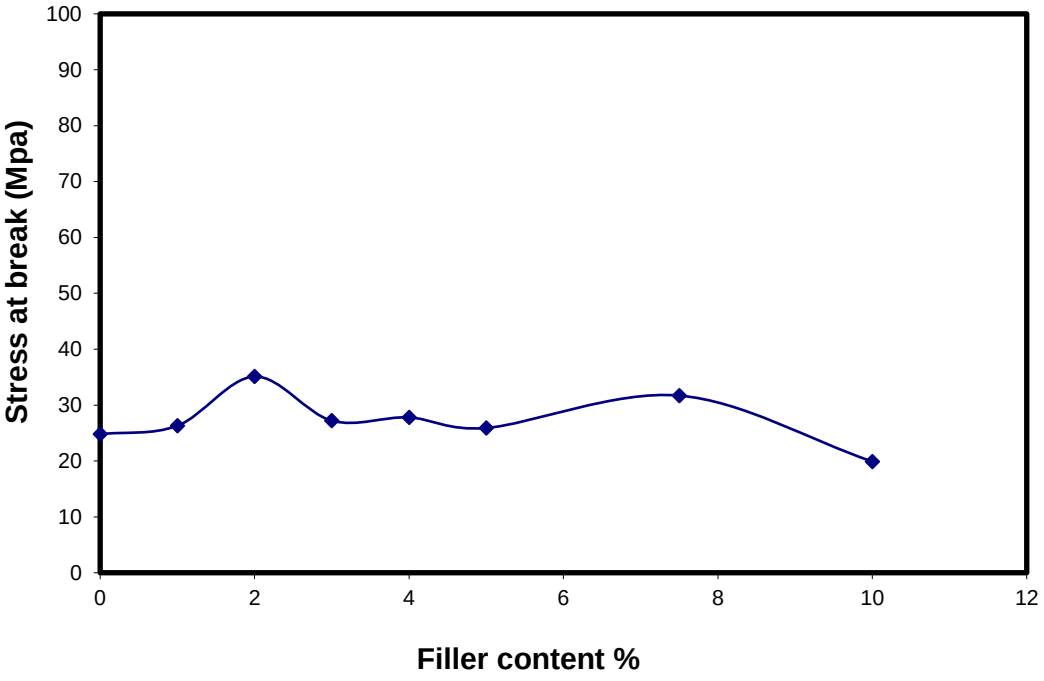


Figure (11) relationship between tensile strength at break of PP/PFA composites.

Conclusion

As a result of the homogeneous distribution of filler powder with the polymer, experimental results indicated that adding palm frond ash (PFA) to polypropylene (PP) has a significant effect on the mechanical properties and that (2 wt.%) of the powder additive was the best for the hardness of the mixture, which is estimated at (35.1 MPa), and the ratio (2 wt.%) is the best for the elasticity of the polymer, also the greatest value of Young's modulus, which is 5.69 MPa, was recorded at the ratio (4 wt.%); also, the behavior of the melting temperature and thermal conductivity were increased after the adding process of palm frond ash to the polypropylene. Compared to the other weight ratios, the polymer polypropylene with a (2%) addition of palm frond ash powder offers a more uniform range of uses.

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