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Research article

Develops New Composite Materials for Prosthetic Foot Industry

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Abstract

This work concerns developing two types of composite materials, which can be used in manufacturing the prosthetic foot with a reasonable cost and satisfying mechanical properties accepted. The cross-linking of composites was performed in some selected cases. The composite characteristics were investigated by mechanical tests (tensile properties and Charpy impact strength). It was found the Young's modulus of 40% high density polyethylene (HDPE) filled with 60% date palm wood (DPW), significantly increased to 80% compared with those values of pure HDPE. Moreover, the yield and ultimate stresses were improved, which was approximately 2 times higher than that observed for neat HDPE, whereas the elongation at break and impact energy were decreased significantly. On the other hand, it has been noticed that adding 10% of linear low density polyethylene (LLDPE) to 90% HDPE increasing from elongation at break to 27% compared with those values of pure HDPE while the ultimate, yield stress and impact energy have been decreased.

Keywords: Energy absorption, Impact test, Polymer, Prosthetic foot, Tensile test.

Introduction

Recently, there are several researchers have studied prosthetic foot designed and manufactured from polyethylene. It has good characteristics when compared with the SACH foot, such as good dorsiflexion (4.2o and 1.9o), stored energy return (58.9 and 13.14), the force transmitted at impact heel (154N and 205N), the effective length ratio (0.76 and 0.64) and life of faith (1233417 and 896213) cycles [1]. High density polyethylene (HDPE) is made by low pressure methods. In this method, pure ethylene is polymerized at a pressure of about 50 atmospheres and temperature between 60-200 c^{o} in the presence of the Zeigler Natta catalyst system and supported oxide catalyst [2]. Such polymers are over 90% crystalline, sufficiently linear compared with low density type and density above 0.95g/cm^{3} [3]. These new low density polyethylene (LDPE) has increased linearity, with a smaller amount of alpha olefins as co-monomers, density range of 0.918-0.940g/cm^{3} and are referred to as linear low density polyethylene (LLDPE) [4]. Linear low-density polyethylene (LLDPE) is an important member of the family of polyethylene which has better mechanical strength and processability than high-density polyethylene (HDPE) due to the presence of short-chain branches [5]. The linearity in the polymer structure imparts better tear and tensile properties, while the chain branching caused by the alpha-olefinic co-monomers, account for the inherent toughness of the LLDPE resin. It is tougher and has better tensile and impact properties, higher stress crack resistance and puncture energy. It also has better sealing characteristics and yields cheap end products by allowing up to 30% down-gauging when compared with LDPE [6, 7]. The fibers prepared from the date palm are important, especially in countries in which date palm tree production is high [8]. Wood fibers are among the most frequently used natural materials; however, other natural fibers, such as flax, hemp, cotton, jute, banana, ramie, sisal, coir, and date palm fibers, are often employed [9]. Date palm wood powder/glass fiber-reinforced hybrid composites blended with recycled polypropylene [10]. The fibers prepared from the date palm are important, especially in countries in which date palm tree production is high. Several researchers have studied composites by preparing polymeric matrices from date palm fibers [11]. There are more ways of reinforcing polymer composite was fabricated to mixing LLDPE with oyster shell powder using injection molding machine [12]. The introduction of HDPE can improve the toughness of PP at no expense of the stiffness [13]. This paper investigates the mechanical properties of composites based on linear low-density polyethylene (HDPE, LLDPE) blended with date palm wood powder (DPW). The purposes of this study were to evaluate and get new properties that require the flexibility to apply on the prosthetic foot.

2. Experimental works

2.1 Water Absorption

Water absorption was determined gravimetrically. The powder was conditioned in a vacuum oven at 80 c^{o} for 24 h. It is observed that all the LLDPE, HDPE and DPW powder composites investigated generally showed an increase in water absorption with an increase in DPW content. Furthermore, it is also observed that the amount of water absorbed at any given filler content decreased with a reduction in the particle size of filler of date palm wood. The

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presence of DPW strongly affected the water absorption of the composites. The water absorption test revealed that the composites had a strong tendency to absorb water, which was dependent on the filler content.

2.2 Preparation of LLDPE and HDPE Blends and Filled with DPW.

A sensitive electronic read-out weighing machine, Italy 1700 Model was used to measure a 100g of each blend portion of the LLDPE and HDPE pellets respectively. The blend ratios obtained by mixing LLDPE and HDPE resins are shown in Table 1.

Table 1: Blend Ratio (w/w)

Blend	1	2	3	4	5	6
HDPE (g)	100	90	75	50	25	0
LLDPE (g)	0	10	25	50	75	100

where w is weight of a mass of blends in grams. Each of the blends was pulverized, using a mechanical blender to ensure thorough mixing. The blended composition was charged into an injection machine. The following operating conditions: die-head temperature of 183+10C and 120 bars. The blend composition was then passed through the die head orifice of the injector which determines the thickness of the blown films. In addition, to prepared composite materials using amount of 60 (g) of DPW blended with 40 (g) of HDPE, as well as 50 (g) of DPW mixed with 30 (g) of LLDPE and 30 (g) of HDPE, however to show the advance that may happen in mechanical properties of composite. Moreover, to improve the mechanical properties of LLDPE using 60 (g) of it mixed with 40 (g) of DPW as shown in Table.1.

3. Preparation specimen

In order to prepare the specimen shoulddesign, moldd that made of iron as shows in Figure 1. The blended composition of dimensions 20cm x17. 5 cm x5mm as shows in Figure 2 was charged into molding. The specimen of composites was prepared by using ASTM D638 and Surfcam program and CNC milling machine Model XK7124 with feed rate 1000 and speed relative to the blend ratio, where shown LLDPE require high speed than HDPE to avoid to Peels or bulge as shown in Figure 3.

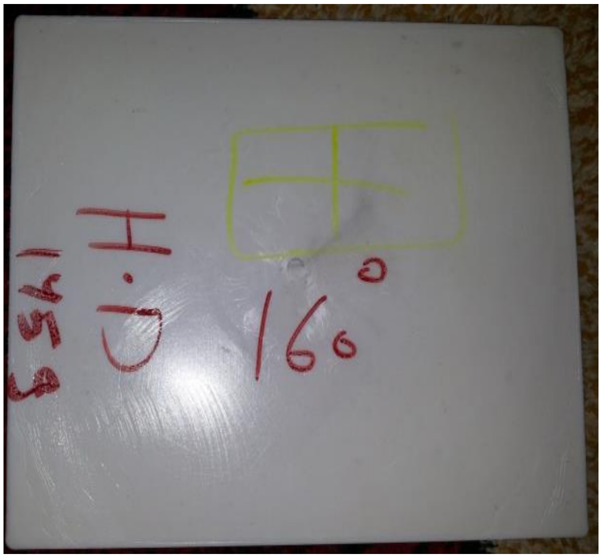

Fig.1: Molding of Injection

Figure 2: Sample Piece.

Figure 3: The specimen of tensile test.

4. Tensile Properties

The yield strength and Young's modulus of the films, were determined using parallel-strip tensile test piece according to ASTM D638 using a testing machine. The films were cut into parallel strip specimens and conditioned at a temperature of 23+0.50C, relative humidity of 50 + 2% and tested for tensile strength at a crosshead speed of 50 mm/min.

5. Impact Test

For impact testing, Charpy impact was used on un-notched (because notched require measure the remain area and when used in Charpy just to focus the frailer in the center of the specimen). The test specimens was carried out on an Impact Tester using pendulum hammer 5 J striker at a striking velocity of 3.46 m/s in accordance with ISO179. Specimen dimensions were (55mm x 10mm x 5mm), where test worked on testing impact machine New York. A sharp blow on the specimen breaks the test piece and the impact was recorded from the analog read out where the error of the device was 15%.

6. Results and Discussion

6.1. Mechanical properties of LLDPE and HDPE blends.

In this part, we characterized the mechanical properties of the composites tested in the tensile mode at room temperature (25C^{o}), in the bending mode at room temperature. Table 2, shows the effect of the additive of LLDPE on the mechanical properties of HDPE blend, tensile strength at yield, ultimate stress, modulus of elasticity and impact energy.

Table 2: Mechanical properties of blends at 25C^{o}. The x/y notation represents the LLDPE/HDPE w/w ratio.

Parameters	**Blends ratio of LLDPE/ HDPE blend w/w (g)**					
	0/100	10/90	25/75	50/50	75/25	100/0
Yield stress(MPa)	18	18	14	12	11	10

Ultimate stress(MPa)	26	26	21	19	18	16
Modulus of elasticity (GPa)	1.00	0.7826	0.560	0.387	0.275	0.16
Density(kg\ m^3)	950	946	942	939	933	928
Energy(J)	3.95	4.1	3.8	3.55	3	2.8
Cross section exact area(mm^2)	9.95*4.66	10.15*4.75	10.02*4.92	10.8*4.71	9.96*4.56	10.86*4.7
Impact energy (KJ/m^2)	85.2	85.04	77.24	69.8	66.054	54.86

The stress–strain curve of unfilled HDPE is illustrates in Figure 4. They observed that the strain at break less than in the composite, where that return to the stiffness of HDPE, which is characterized by the Young's modulus. The maximum value of 1 GPa for the pure HDPE. Figures 5,6,7,8 and 9 shows that the modulus of elasticity increase with a decrease in the amount of LLDPE concentrations in the blends. The decrease in impact energy is, however contrast with earlier studies as linearity generally imparts strength. It can be noticed that the values of impact energy significant decrease when mixed HDPE with LLDPE, where the minimum value of impact energy was 54.84 KJ/m^2. The result showed that with increasing LLDPE concentrations, the elongation at break of the composite increased. Although the mechanical strength of a polymer film can be assessed from impact and tensile tests, which are expected to be high, it is hardly possible to obtain high impact energy at the same time from a given polymer [3]. It is also evident from Figure 4 that the ultimate stress decreased from 26 MPa in pure HDPE to 10 MPa in pure LLDPE as shows in Figure 9. A slight decrease was noticed in the properties at the add 10 g of LLDPE to HDPE, where the impact energy reduces from 85.2 in HDPE to 85.04 in LLDPE which demonstrated in Table 2. There is increasing elongation at break in any edition, where elongate from 0-95% at HDPE and reduced at LLDPE from 0-490% on stress strain curve as shows in figures 4 and 9. The increase in the yield stress indicates a reinforcing action of the HDPE on the LLDPE resin. They observed that there was decreased in the yield stress that a material is at a higher strength before the application of stress, and as stress is applied to it, the material slacks in tension, with a tensile strength decreasing at the yield point. As the LLDPE loading increased in the blend, the more or less rigid material became less rigid and therefore prone to creep [14].

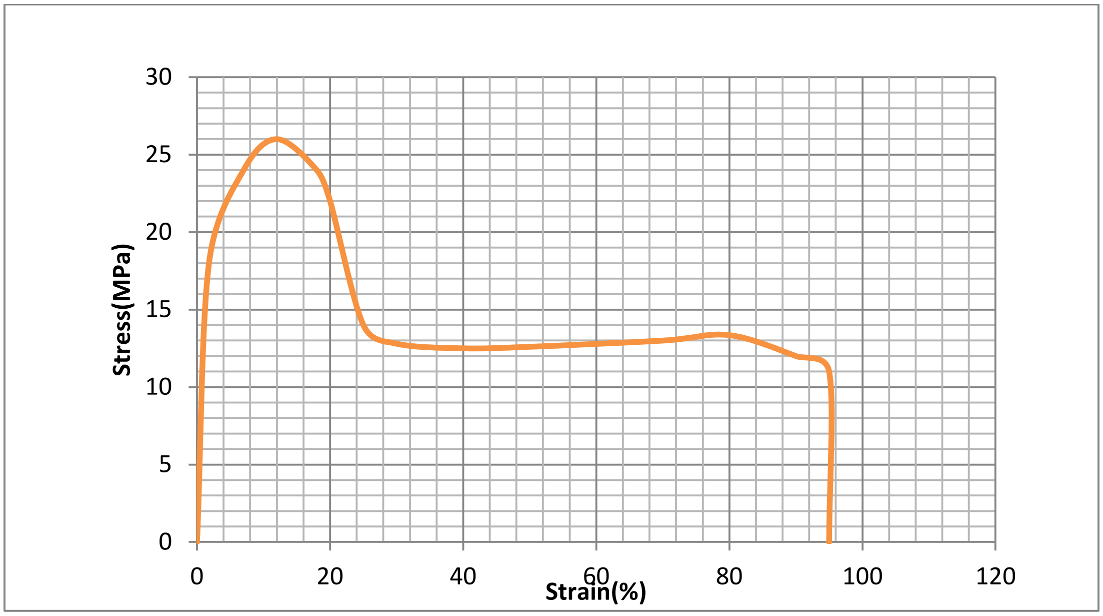

Figure 4: Stress-strain curve for HDPE.

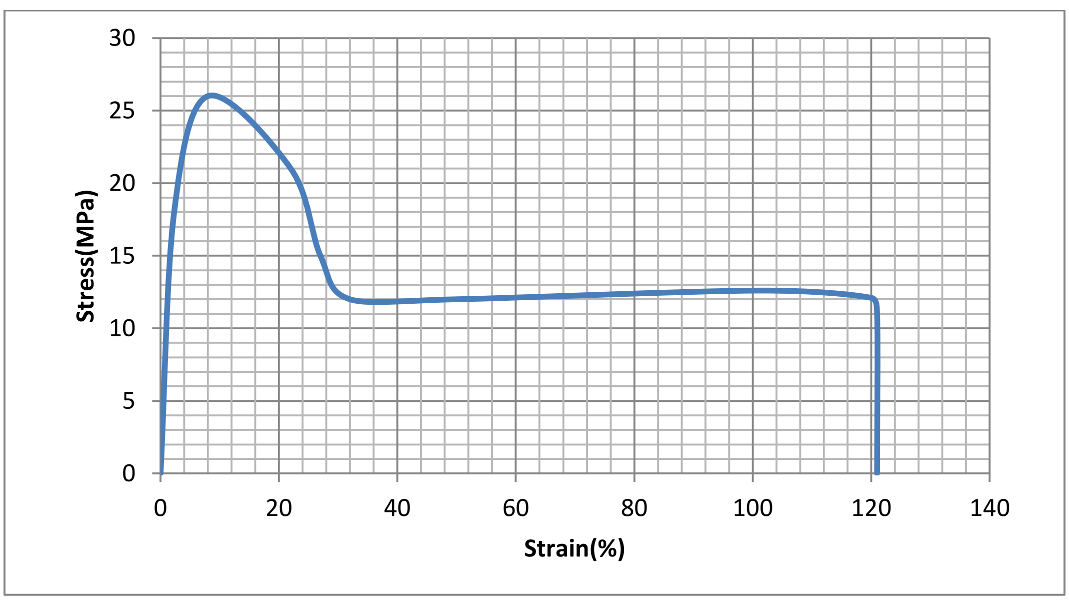

Figure 5: Stress-strain curve for (10%) LLDPE/ (90%) HDPE blends.

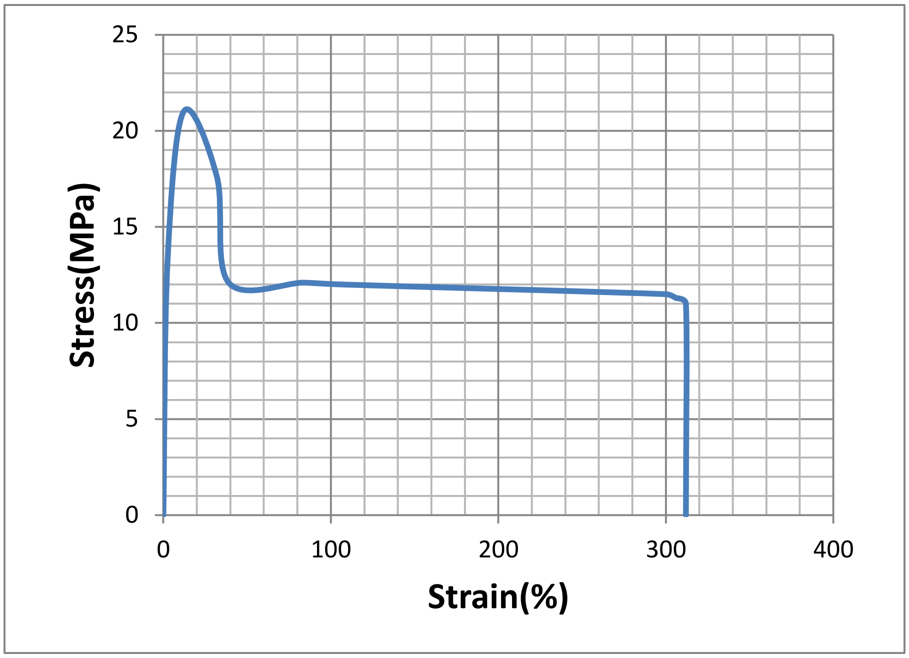

Figure 6: Stress-strain curve for (25%) LLDPE(25%)/ (75%) HDPE blends.

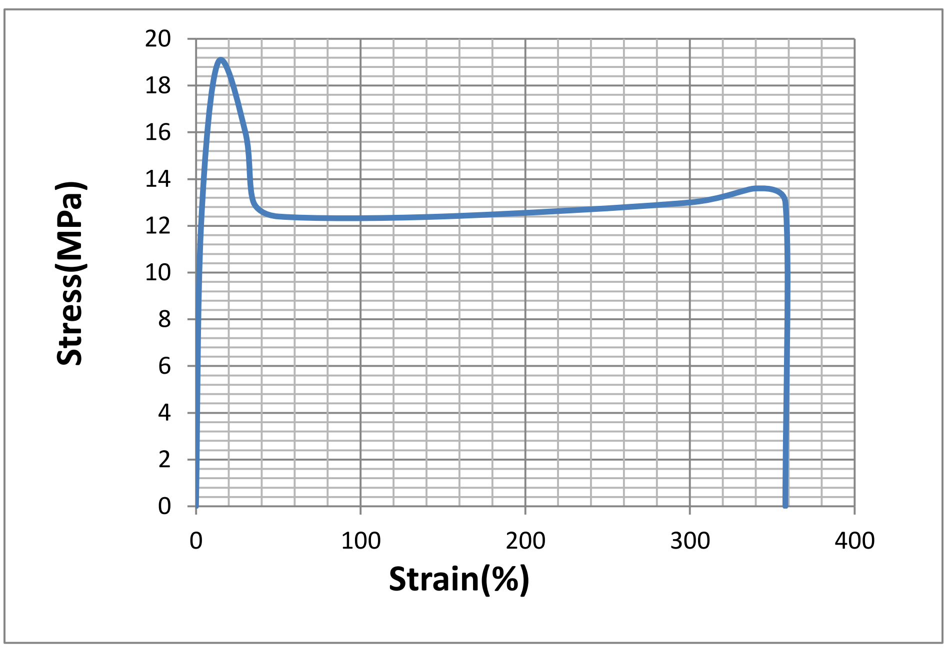

Figure 7: Stress-strain curve for (50%) LLDPE/(50%)HDPE blends.

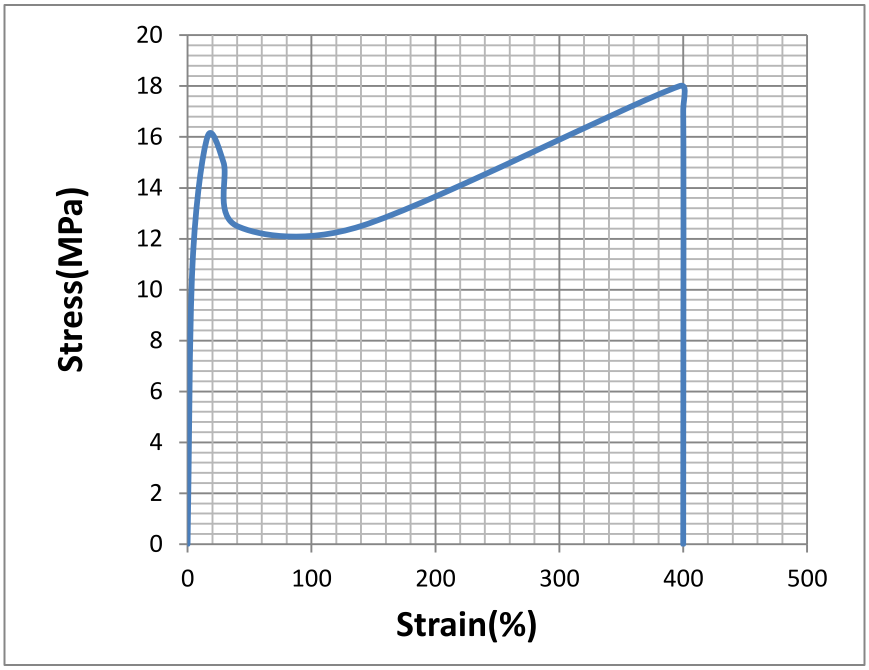

Figure 8: Stress-strain curve for (75%) LLDPE/ (25%) HDPE blends.

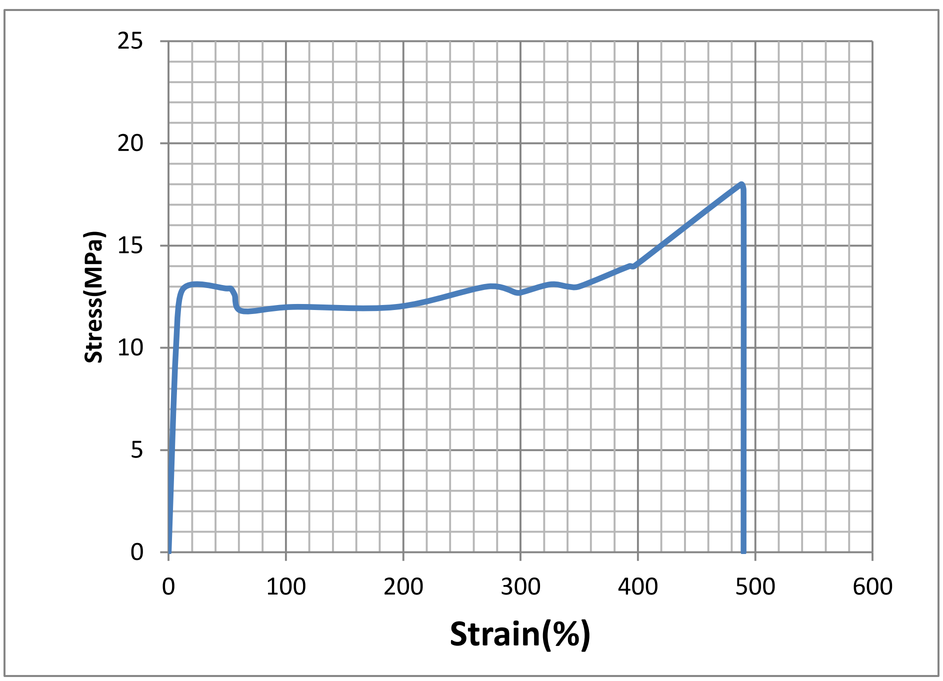

Figure 9: Stress-strain curve for LLDPE.

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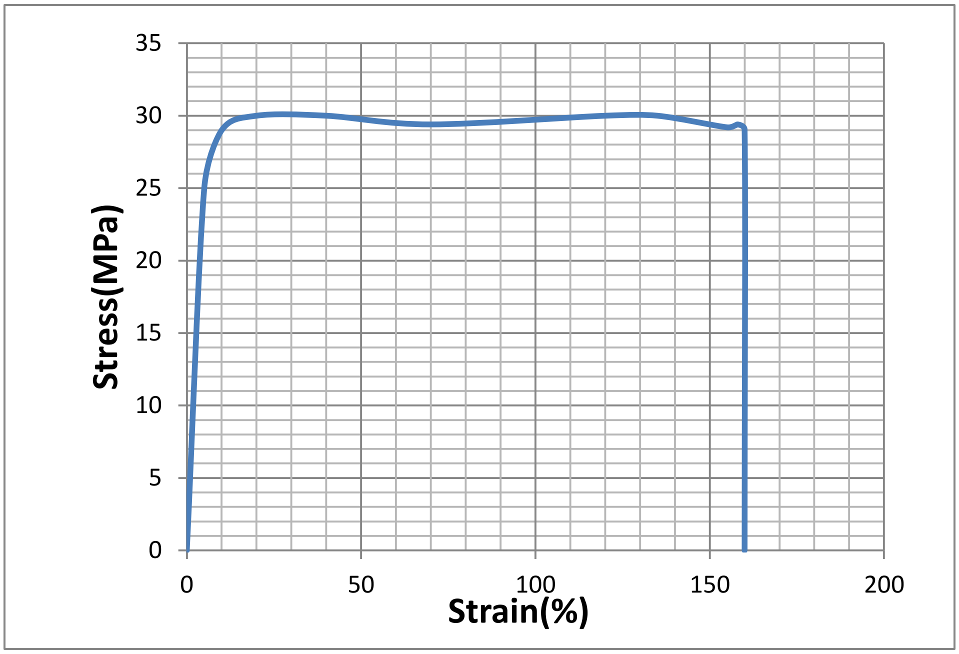

Figure 10: Stress-strain curve for (60%) LLDPE/ (40%) DPW.

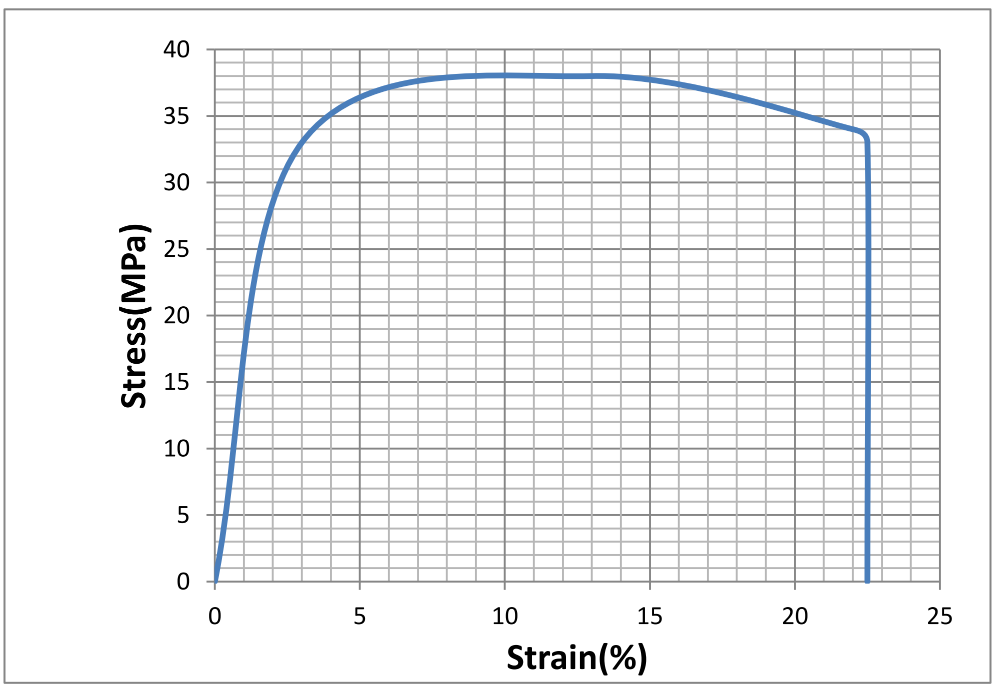

Figure 11: Stress-strain curve for (30%) LLDPE/ (30%) HDPE (50%) DPW. (60%) LLDPE/ (40%) DPW.

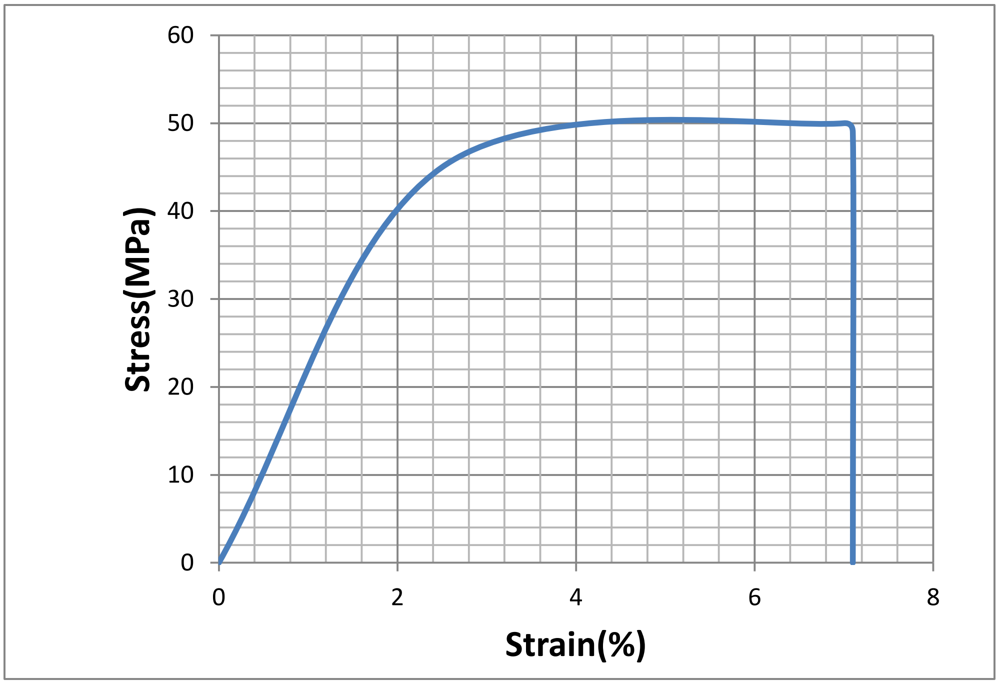

Figure 12: Stress-strain curve for (60%) PE/(40%)DPW. (60%) LLDPE/ (40%) DPW.

6.2. Mechanical properties of composite materials.

The stress–strain curve of composite was prepared of LLDPE (60g) with DPW (40g) as in shown Fig.9 and Fig.10. It is evident from these figures that the yield stress, increased from10MPa to 25MPa and ultimate stress from 26MPa to 30MPa. Additionally the Young's modulus was increased from 0.16GPa to 0.5GPa that explain in the Table 3. Also demonstrate that the properties of LLDPE (30g)/HDPE (30g) blends filled with DPW (40%) compare with Figure 7 increased of yield stress from12MPa to 33MPa and ultimate stress from 19MPa to 38MPa, moreover the Young's modulus was increased from 0.4GPa to 1.1GPa as shown in Fig.11. However, this paper focus on the study of properties to design a prosthetic foot from new available and low cost material, therefore the purpose of use HDPE reinforced with DPW to get best mechanical demonstrate that when mixed HDPE (40g) with DPW (60g) increased of yield stress from18MPa to 45MPa and ultimate stress from 26MPa to 50MPa as shown in Fig.12.

Table 3: Mechanical properties of composites at 25C^{o}. The x/y notation represents the LLDPE/HDPE/ DPW w/w ratio.

Parameters	**Blends ratio of LLDPE/ HDPE/DPW blend w/w (g)**		
	60/0/40	30/30/40	0/40/60
Yield stress(MPa)	25	33	45
Ultimate stress(MPa)	30	38	50
Modulus of elasticity (GPa)	0.5	1.1	1.8
Density($kg\backslash m^3$)	945	953.4	961.6
Energy(J)	2.745	3.495	3.895
Cross section exact area(mm^2)	10.86*4.7	10.8*4.71	9.95*4.66
Impact energy (KJ/m^2)	53.78	68.71	84

An increased in the of Young's modulus from 1.1GPa to 1.8GPa as shown in Fig.4 and Fig. 12. According to the values that got from the impact test, observe decreased in the energy impact as shown in the Table 3. To reduce of the cost of the materials used Recycled linear low-density polyethylene (RLLDPE) was blended with date palm wood powder (DPW) [15]. Thus, tie-molecules are important for all strength properties of polyethylene. Hence the increasing concentrations of LLDPE introduced tie-molecules into the polymer blend.

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Conclusion

In this study, two different of composite materials HDPE/LLDPE and HDPE/DPW powder composites have been developed. The preparation has been done mold injection. Also, a fine powder with a fibrous shape was prepared from date palm wood (DPW) by grinding. The mechanical properties viz., impact energy and tensile such as yield stress, ultimate stress and modulus of elasticity the specific conclusions of the study are: It was found that the elongation at break, significantly increased by 21.5% by using a mixture of the blends of (90g) HDPE with (10g) LLDPE, which consequently decreases the stiffening effect of the blinds, which were characterized by the modulus of elasticity. The addition of the yield and ultimate stresses of the blends remained at the same value of pure HDPE. Furthermore, it showed that the yield and ultimate stresses, significantly increased by 60% and 44% frequently with mixed the blends of (40g) HDPE with (60g) DPW. Overall, it was observed that the modulus increased by 80% compared with pure HDPE with a slightly decreased in the impact energy by 1%. However, further increases in the filler content caused negligible influences on the stress at break of the composites, which indicated a low interfacial interaction between the polymer and the filler. Generally, the results obtain in this work propose using to manufacture of prosthetic foot.

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