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Research Article

Effect of Sawdust Wood on some Mechanical properties of Recycled Polyethylene Terephthalate (RPET)

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Abstract

The waste disposal is the main challenge in every country. The plastic usage is increasing day by day. Plastic wastes causes environmental pollution and depletion of landfill space . This study includes recycling of consumed transparent water bottles made from polyethylene terephthalate (PET) to prepare materials with properties valid for use in some construction field. This study includes preparing first set of recycled polyethylene terephthalate (RPET) with different melting temperature (180°C ,200°C ,220 °C , 240 °C) and mixing times (10,20,30,40,50 and 60 min) .50 minutes mixing time was chosen for mixing time .The second set of RPET composites filled with different weight Percentage of sawdust wood (10% , 20% ,30% , 40% , 50% and 60%) .Weight percentage 30% of sawdust wood was chosen for RPET/S.D.W composites . Samples for mechanical tests (compression, Charpy Impact , wear test) for the first set of RPET and RPET/S.D.W composites were prepared . Eight samples (A , B , C , D , E, F, G , H) from RPET and RPET/S.D.W composites were prepared for Compression test .The results showed that the samples A , B for recycled polyethylene terephthalate acquired maximum stress 31,26 N/mm^2 and 30,09 N/mm^2 respectively at melting temperature 180 °C , 200 °C and the samples did not fail and 33,10 N/mm^2 for sample E of RPET/S.D.W composites at melting temperature 180 °C sample did not fail too in the same conditions with increase about 6.5 % when adding sawdust wood . Eight samples(I , J , K , L , M , N , O, P) for RPET and RPET/S.D.W composites were prepared for Charpy impact test. The best results of impact resistance value 4.9 KJ/ m^2 was found for sample I of RPET at melting temperature 180°C . Eight samples(Q , R , S , T , U , V , W, X)for RPET and RPET/S.D.W composites were prepared for wear test . Lowest wear rate value 0.99 × 10^{-7} gm / cm was observed for Sample Q prepared from RPET at melting temperature 180°C. It is concluded that RPET samples prepared at 180°C and 200°C and RPET/S.D.W composites prepared at 180°C show best results for compression test and concluded RPET samples prepared at 180°C show best results for charpy impact and wear test.

Keywords: *Recycled PET, Sawdust Wood, Compression, Charpy Impact, Wear test*

Introduction

Plastics consumption now days have become an integral part of our lives. The amounts of plastics consumed annually have been increasing steadily. There are several factors that contribute to the rapidly growth of plastics consumption such as low density, fabrication capabilities, long life, lightweight, and low cost of production. plastics waste are major cause of environmental and social problems causing loss of natural resources, environmental pollution, and depletion of landfill space . The management of plastics waste is one of the major problems facing modern society as it non degradable and toxic when burned. Poly ethylene terephthalate (PET) is one of the highly requested plastic in the world and among the most common plastics waste. PET is thermoplastic polyester. PET has Low water absorption, high hardness and strength and PET used in various applications like food container, bottle, plastic fibers, toys, wrapping materials, films and resins , despite all of the benefits but PET remain in the environment (D. Wahab ,2007; A. Oromiehie *et al* ,2004) . It is observed that 45-50 per cent of original wood (timber) taken for mechanical processing ended in waste (Sawdust wood) . It can present a hazard in manufacturing industries, especially in terms of its flammability .Recycling is the best way for reduce plastic solid waste in the environment and reducing carbon footprint (R. Maharani *et al*, 2010; M.Ozalp ,2011). Many researchers reported review of the work carried in the field of recycled PET bottles. (Frounchi *et al* , 1997), prepared blends of 20 W/W % recycled RPET with virgin PET in counter-current mode at screw speed of 62 rpm and temperature profile of 235 °C to 260 °C. Practically the mechanical properties (Impact resistance , tensile strength) with its molecular weight slightly lower than virgin PET were reported.

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(S.khoramnejadian,2011), study recycled waste PET bottle with polycarbonate ,alloy prepared in twin-screw extruder with 150 rpm at 260°C. Tensile strength decreased during recycling process. Polycarbonate for improving of recycled PET. (K. Rahman *et al* ,2013)Studied the prepared of composite matrix from saw dust (S.D.W) and recycled PET bottle with different ratio (w/w) mixing the saw dust and PET in a rotary type blender followed by flat press method. Modulus of Elasticity and Modulus of Rupture were reached to maximum for the fabricated composites (2008.34 and 27.08 N/mm^2, respectively) when the S.D.W content were only 40% . (Y. Choi et. al,2009) reported that the waste PET light weight aggregate (WPLA) obtained from recycled PET bottles at water/cement of 0.49, the structural efficiency (compressive strength / density ratio) of concrete containing 25 % WPLA was higher than that of for the normal concrete. Many studies have been conducted on the recycling PET bottles and used with cement, (H .Binici, 2013) ,(M. Kuniyuki et. Al, 2004) , (Y. Marzouk,2005), and (D . Foti, 2013) have reported recycled polyethylene terephthalate (PET) were appropriate to concrete reinforcement and improvement in ductility of the concrete. The main objectives of this study is to prepare samples and mechanically tested for RPET and RPET/S.D.W composites. The research aims to study the compression, charpy impact and wear test for samples .

Experimental procedure

Materials used

Consumed transparent water bottles made from Polyethylene terephthalate with weight of each bottle 5.55 gm after cutting upper and lower part of bottles with thickness 0.16 mm were used. The FT-IR spectrum for PET was measured at temperature is shown in figure (1).

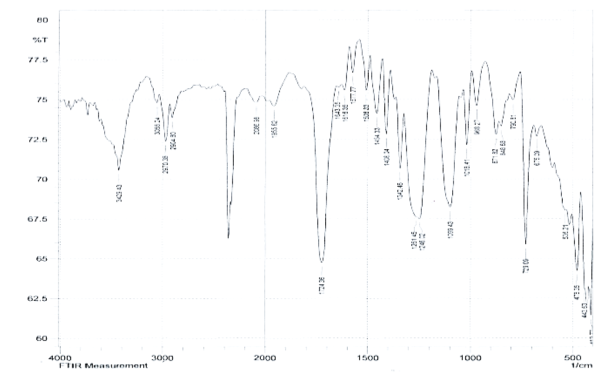

Fig.1 FTIR spectra of PET bottle

The peak at 3429.43cm^{-1} is for stretching bond of O-H, peak 2970 cm^{-1} is for stretching bond of C-H , peak 1724 cm^{-1} is for bending bond of C-H ,peak 1575.35 is for stretching bond of C=C , peak 1342.46 cm^{-1} stretching bond of C=O bond ,peak 729 is for stretching bond CH2 . Which agree well with the results reported , (Ö Çepelioğullar *et al* 2013).

Sawdust wood (S.D.W) obtained from local carpentry and wood -working processes with average lengths about 5-20mm and thickness about 1.05 mm was used.

Preparation method

Recycling PET samples (RPET)

In order to prepare RPET samples, 50 empty pre-used transparent water plastic PET bottles were collected ,in order to be used for the process of plastic recycling that can be reused in different useful fields of engineering construction . All the commercial sticker labels were pealed and removed from the bottles and then were cleaned and dried. Also the neck and the base of each bottle were excluded were not used. Each bottle (of net weight of 5.55gm) was shredded to small pieces by an ordinary scissors; each piece is approximately of 30*20mm in dimension and recycled at different melting temperatures, with best results obtained at 180˚C , 200˚C, 220˚C and 240˚C. The RPET samples were melted by placing them in a pot and heating the contents at 180°C for 10 minutes . For The first sample same process was repeated for different intervals of time (20,30,40,50 and 60 minutes). The melted contents then were poured in containers for measuring mechanical test (compression ,charpy impact and wear test), They were left for 24 hours to have the solid sample, were then taken out of the containers .The whole process was repeated for RPET samples at heating temperatures of 200˚C, 220˚C and 240°C respectively. It was noticed that the best results were obtained at melting time of 50 minutes.

Preparation of RPET/S.D.W composites

It is necessary to remove the residual moisture in the sawdust wood which would greatly affect the properties of the composite. For this reason, the sawdust wood was dried in an oven at 100 ± 2°C for 24 hours. The same processes of melting mentioned above were repeated and except that at 15 minutes from the end of the melting process, a different weight percentage (10%,20%,30%,40%,50% and 60%) of sawdust wood) was added each time to the pot and well mixed with the contents in order to obtain a homogeneous mixture. Weight percentage 30% of sawdust wood was chosen to obtain optimum conditions . The melted contents then were poured in standard containers for measuring the compression, charpy impact and wear tests.

Mechanical Tests

1-Compression test

A compression test is eight samples prepared (A,B,C,D,E,F,G,H) for RPET and RPET/S.D.W composites according to the ASTM- D695 are shown in Figure(1) and (2), Compression test method for determining the behavior of materials under a compressive load preparation of the samples.

Fig.1 RPET samples with different melting temperature A – at 180°C ,B-at 200 °C, C-at 220 °C and D- at 240 °C for compression test

Fig.2 RPET/ S.D.W composites with different melting temperature E-at 180 °C ,F-at 200 °C, G-at 220 °C and H- at 240 °C for compression test

It then calculate the value of stress for each sample of the equation (1) and the value of the strain of the equation (2) , It is then draw a relationship between Stress and Strain of each sample.

$$\sigma = \frac{F}{A_0} \tag{1}$$

$$\varepsilon = \Delta L/L \tag{2}$$

Where F is the force , A_0 is the area of the plane , the elongation $\Delta L= L-L_o$ and L, L_o are the instantaneous and original length respectively, of the relationship between stress -strain curve by equation (3) calculated Young's modulus.

$$\sigma = Y\varepsilon \tag{3}$$

Where (Y) is the modulus of elasticity (Young modulus) (V. Gowariker 1986; M . Waheed *et al* ,2008).

2-Charpy impact test

The impact test is different from the rest of the mechanical tests because the specimen will be subjected to the rapid stress.

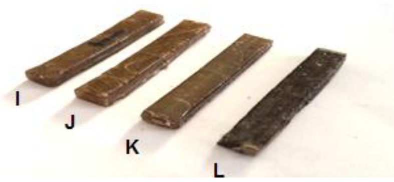

Fig.3 RPET samples with different melting temperature I-at 180 °C ,J-at 200 °C, K-at 220 °C and L-at 240 °C for charpy impact test

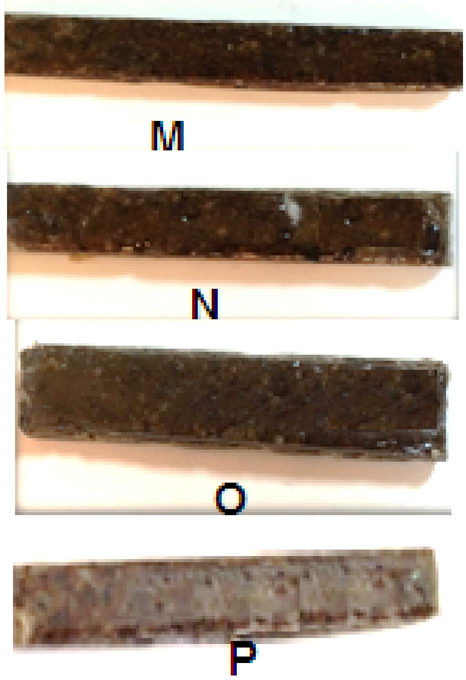

Fig.4 RPET/ S.D.W composites with different melting temperature M-at 180 °C , N – at 200 °C, O –at 220 °C and P – at 240 °C for charpy impact test

The impact test RPET and RPET/S.D.W composites samples (I,J,K,L,M,N,O,P) prepared according to the **ISO-179** are shown in Figure(3) and (4) .

Charpy Impact method was were to measure the impact strength (I.S).By using the following equations (4).

I.S =E/A (KJ/m²) (4)

Where I.S = impact strength ,E = Energy of fracture in (kilo joule),A = Cross section area in (m^2) (D. William *et al* ,2009).

3-Wear test

Wear test is the removal of material from or the impairment of The solid surface resulting from friction or impact. Wear test method type pin on disc. The Wear test eight for RPET and RPET /S.D.W composites samples(Q,R,S,T,U,V,W,X) prepared according to the ASTM 99G are shown in Figure(5) and (6).

Fig.5 RPET samples with different melting temperature Q– at 180 °C , R –at 200 °C ,S –at 220 °C and T –at 240 °C foe wear test

Fig.6 RPET samples with different melting temperature U – at 180 °C , V –at 200 °C ,W –at 220 °C and X –at 240 °C for wear test

The influence of different normal loads (5,10,15 and 20 N), on the wear rate of the un-reinforced and reinforced composites at constant parameters ,rotating disc speed 500 rpm, time 10 min, Which it is to know the sliding distance from eq (5) equal 251200 cm . Wear test method was were to measure the wear rate(W.R). By using the following equations (6)

$$\mathbf{SD = 2\ \pi Nrt} \quad (5)$$

$$\textbf{Wear rate (W.R)} = \Delta W/SD \quad (6)$$

Where S_D: is the sliding distance (cm), t : is the sliding time (min) and ΔW: is the weight loss of the specimen before and after the wear test (g) (B. Dhyaa *et al* 2011).

Results and discussion

I-Compression test

Compression test value for RPET samples are shown in the table (1).

Table 1 Compression results for RPET samples

Sample	Max stress ($N.mm^{-2}$)	Youngs modulus (GPa)
A	31.26	0.54
B	30.09	0.45
C	24.52	0.31
D	21.18	0.36

From the table (1) the results show a decrease stress maximum for RPET samples with melting temperature increase. The best result for the melting temperature are 180 ^{0}C and 200 ^{0}C . Where maximum stress borne and did not fail for samples A, B .

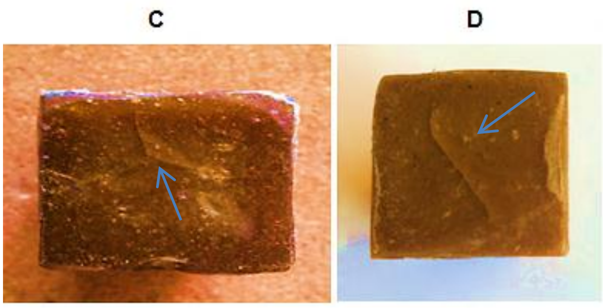

Fig.7 The vertical views cracks for C,D RPET samples

The increase melting temperature led to the failure for samples C and D when the maximum stress shouldered samples, are shown in the figure(7) , which shows the vertical or vertical views spread the cracks

Young's modulus decreased with increasing melting temperatures is shown in figure (8), this is due to the disposition of the molecular chain of PET suffer thermal degradation increasing melting temperatures, leading to the possibility of fracture some of the chain, which means that the molecular chains of the thermal degradation of PET are subject to further processing. It also reduces the viscosity of the melt with lower molecular weight, it can be expected that the loss in molecular weight after each operation, could adversely affect the process. Different mechanisms lead to the deterioration of the molecules with the carboxyl end groups and ethylene (K . Rahman *et al* ,2013). The Young's modulus can be compared to samples RPET with a Young's modulus of the Virgin PET where equals 1.7 GPa (B. Park *et al*, 2007). .

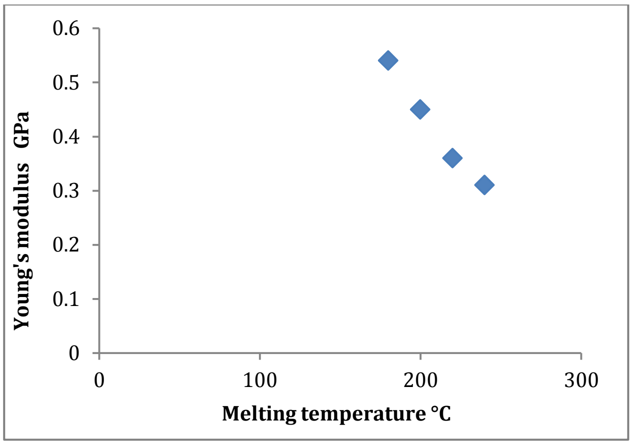

Fig.8 Young's modulus vs different melting temperature

As for the RPET/S.D.W composite. The results obtained are shown in the table (2).

Table 2 Compression results for RPET/S.D.W composites

Sample	Max stress ($N.mm^{-2}$)	Youngs modulus (GPa)
E	33.10	0.28
F	23.57	0.23
G	20	0.20
H	18.95	0.19

From the table (2) the results show the stress maximum is decreased for RPET/S.D.W composites samples with melting temperature increase. The best result we get is melting temperature at 180 ^{0}C. Where maximum stress borne for sample E and doesn't fail , when add particulate filler (S.D.W) to the composite material it will impede the cracks movement. Sawdust wood is working impede or will impede the cracks movement and absorb the stresses inflicted upon. The results show that when the melting temperature increase leads to failure (F, G, H) samples, is shown in the figure (9), it is due to deterioration the molecular chain for PET and deterioration of sawdust wood and lose their properties leading to the possibility of burned.

Young's modulus decreased with increasing melting temperature is shown in figure (10).

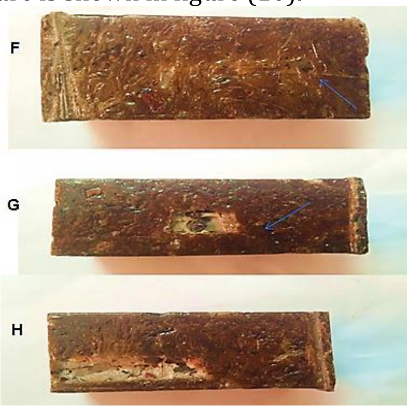

Fig.9 Illustrates Failure for F, G and H composites

This variation might be due to the poor interfacial interaction between the sawdust and RPET, as a result the thermoplastic (PET) might not flow well within the composites reported that the lower Young module of the composites could be mainly attributed to the poor interfacial interaction between the polymeric matrix and wood particle, not allowing efficient stress transfer between the two phases of the material though the modulus of the natural fibers are higher than the polymeric materials. The result Compared results obtained with by study Rahman (K . Rahman *et al*, 2013).

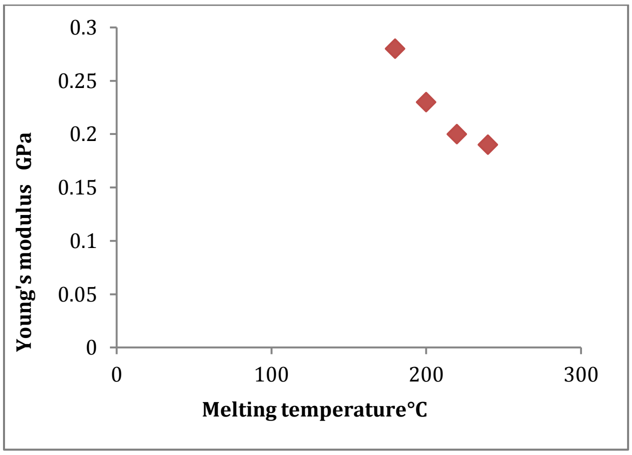

Fig.10 Young's modulus vs different melting temperature

II-Charpy Impact test

Impact strength value (I.S) for RPET samples are shown in the table (3).

Table 3 Charpy impact strength results for RPET samples

Sample	E Kj ×10^{-3}	I.S kJ/m^2
I	0.30	4.9
J	0.28	4.6
K	0.25	4.1
L	0.18	2.95

From table (3) sample A value equal 4.9 KJ/m^2 and best results were obtained at melting temperature 180°. According to the photographic image is shown in figure (11), it can be seen that the fracture surface RPET samples contain some bumps .This shows the that it is not brittle material.

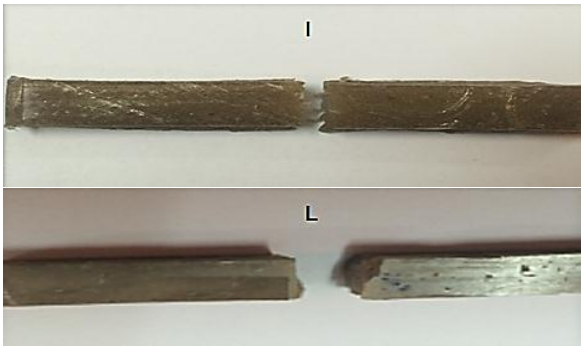

Fig.11 Fracture surface samples contain outcrops

I.S decreased with increasing melting temperature is shown in figure (12). Where the mechanical properties of PET depends large on melting temperature so that the high-temperature lead to the weakening of the chains between repeated units in the polymer which this increase has led to the degradation chains. It can compare the results of the PET Virgin Impact strength and is equal to 9 KJ/m^2(M.Sreekanth,2009).

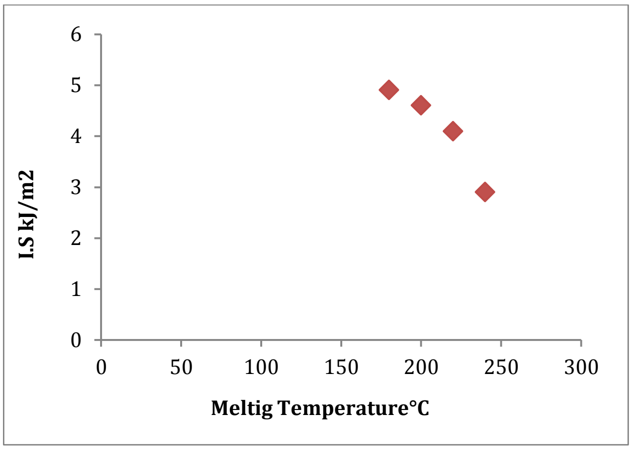

Fig.12 Charpt impact strength vs different melting temperature for RPET

As for the RPET/S.D.W composite the results obtained are shown in the table (4).

Table 4 Charpy impact results for RPET/S.D.W composites

Sample	E kJ ×10^{-3}	I.S kJ/m^2
M	0.17	2.79
N	0.15	2.45
O	0.13	2.13
P	0.12	1.96

The best results Impact strength obtained for RPET/S.D.W composites from the table (4) equal 2.79 KJ/m^2 at melting temperature 180°C. The value impact strength for RPET/S.D.W composites is decreased to half compared with RPET samples. According to the photographic image is shown in figure (13), it can be seen that the fracture surface for samples M and N . Fracture surface contain some bumps.

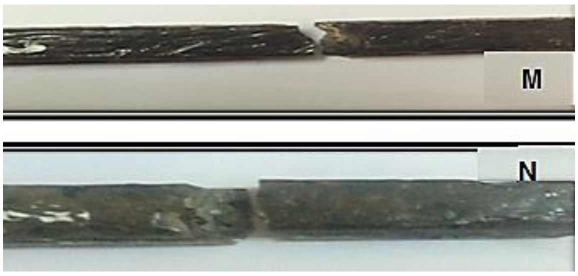

Fig.13 Fracture surface for samples contain outcrops

I.S decreased with increasing melting temperature is shown in figure (14), The high-melting temperature lead to the weakening of the chains between repeated units in the polymer and this is due to the lack of cohesion piece of sawdust wood with RPET.

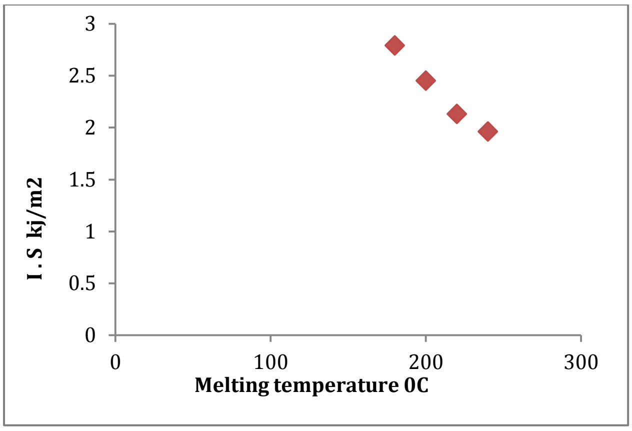

Fig.14 Charpt impact strength vs different melting temperature for RPET/S.D.W composites

This shows that the impact strength decreases with addition sawdust wood of composite materials. This is because of the filler particles, which may represent points for a localized stress concentration, from which the failure will begin, so that the composite tends to form a weak structure. Also, an increase in concentration of fillers reduces the ability of matrix to absorb energy, thereby reducing the toughness, so impact energy decreases M.Sreekanth,2009). The results can be compared with the study carried out by FARHAN who used Unsaturated Polyester resin with sawdust wood was impact strength equal 2.083 kj / m^2 (A. Farhan*et al* ,2011).

3-Wear test

Wear rate value for RPET samples are shown in the table (5), appear all samples increase wear rate with increase applied load. From the table (5) we note that the lowest value is obtained at melting temperature 180 °C. Results show for samples(Q,R,S,T) the wear rate increased with melting temperature increasing. because at higher load, the frictional thrust Increases, The reason can be attributed to an increase in friction force caused due to the friction force is proportional to the load required.

As for the REST/S.D.W composite were tested for samples U,V,W,X and the results obtained are shown in the table (6).

From table (6) the Lowest wear rate value $0.19*10^{-7}$ g/cm for sample U prepared from RPET/.S.D.W composite at 180°C . The wear rate of all samples increases with increased normal load, could be mainly attributed to the poor interfacial interaction between the polymeric matrix and sawdust wood, as well as high temperature between the sample and the disk surface where both surfaces in contact possess a large number of sharp bumps and when a connection between these outcrops biplane under the influence of pregnancy or The warp-speed thermoplastic or remain in the case of elastic contact occurs, but when the bumps are sharp, the effect of stress on the points Acute probably be more flexible stress and deformation of thermoplastic so happens when all the points sharp as the value of the load hanging effect Directly in the plastic deformation that occurs when outcrops near-surface region and tops, as it collects small cracks (Crack) With each occurrence leading to the removal or skimming the surface layers composed has therefore and wear debris that is in the form of sheets Therefore, the thin material deformation increases with increasing load of damocles (O . hamae *et al* 1983) .

Conclusion

Samples obtained from recycling RPET and with additions of sawdust wood (S.D.W) composites show best compression, charpy impact and wear rate values. Sample A and B for RPET show best value of compression at melting temperature 180 °C and 200^{0}C equal 31.26 N/mm^2 and 30.09 N/mm^2 , Respectively .

Sample E for RPET/S.D.W composites the best result compression obtained at 180°C equal 33.10 N/mm^2. Charpy impact test value 4.9 KJ/m^2 was prepared from RPET Sample I at melting temperature

Table 5 Wear rate results for RPET samples

Sample	Melting temperature^{0}c	Wear Rate g/cm load(5N)	Wear Rate g/cm load(10N)	Wear Rate g/cm load(15N)	Wear Rate g/cm load(20N)
Q	180	$0.043*10^{-7}$	$0.43*10^{-7}$	$0.45*10^{-7}$	$0.99*10^{-7}$
R	200	$0.54*10^{-7}$	$0.64*10^{-7}$	$2*10^{-7}$	$6.3*10^{-7}$
S	220	$0.99*10^{-7}$	$1.4*10^{-7}$	$2.7*10^{-7}$	$6.2*10^{-7}$
T	240	$1.45*10^{-7}$	$1.9*10^{-7}$	$8.8*10^{-7}$	$14.7*10^{-7}$

Table 6 Wear rate results for RPET/S.D.W composites

Sample	Melting temperature^{0}C	Wear Rate g/cm at load(5N)	Wear Rate g/cm at load(10N)	Wear Rate g/cm at load(15N)	Wear Rate g/cm at load(20N)
U	180	$0.047*10^{-7}$	$0.095*10^{-7}$	$0.18*10^{-7}$	$0.19*10^{-7}$
V	200	$0.4*10^{-7}$	$0.47*10^{-7}$	$1.6*10^{-7}$	$2.9*10^{-7}$
W	220	$0.75*10^{-7}$	$0.1*10^{-7}$	$1.2*10^{-7}$	$3*10^{-7}$
X	240	$0.76*10^{-7}$	$1.3*10^{-7}$	$3.3*10^{-7}$	$3.3*10^{-7}$

180°C . Lowest wear rate value $0.99*10^{-7}$g/cm was prepared from RPET Sample Q at melting temperature 180°C.

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