CHEMICAL DEPOLYMERIZATION OF WASTE PLASTICS IN BUBBLE COLIUMN REACTOR FOR BLENDED FABRICATION

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ABSTRACT

The degradation of waste plastics in the environment is such an essential issue for Earth protection. This study indicated the importance of using waste bottles to produce recycled depolymerization Polyethylene Terephthalate (DPET). The bubble column reactor technique and its effect in the depolymerization process have been investigated. The DPET with Poly-methyl methacrylate (PMMA) has been used to fabricate the hybrid polymer to improve the mechanical properties. Thus, different percentages (1, 2, 3, 5, and 10 %) of (DPET) are used to surmise its repercussions on the mechanical properties of the polymer. These ramifications were studied through a sequence of research laboratory tests, including tensile strength, Charpy impact, and shore-D hardness, and Fourier Transform Infrared Spectroscopy (FTIR) analysis. The results show a development interest, especially for impact strength and surface hardness, where both tests show compatible results, especially at (10%) of DPET. At the same time, maximum results of tensile strength are at (3%). FTIR analysis shows a chemical reaction between DPET and PMMA, which significantly improves the characteristics and makes it a wide range of available applications.

Keywords: depolymerization, PET, PMMA, Shore-D, Impact strength.

التفكيك الكيمياوي للنفايات البلاستيكية في مفاعل عمود الفقاعة لتصنيع الخلائط

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الخلاصة

يعد التدهور الحاصل في تراكم النفايات البلاستيكية في البيئة أصبح معالجتها قضية أساسية لحماية الأرض. أشارت هذه الدراسة إلى أهمية استخدام قوارير النفايات لإنتاج البلمرة المعاد تدويره بولي إيثيلين تيريفثاليت (DPET). تم دراسة تقنية مفاعل عمود الفقاعة وتأثيرها في عملية تفكيك البلمرة. تم استخدام DPET مع (PMMA)ميتاكريلات لتصنيع البوليمر الهجين لتحسين الخواص الميكانيكية. وبالتالي، يتم استخدام نسب مختلفة (1 ، 2 ، 3 ، 5 ، 10٪) من (DPET) لفحص تأثيرها على الخواص الميكانيكية للبوليمر. تمت دراسة من خلال سلسلة من الاختبارات المعملية البحثية، بما في ذلك قوة الانحناء ، وتأثير تشاربي ، وصلابة السطحية D ، وتحليل فورييه للتحول الطيفي بالأشعة تحت الحمراء (FTIR). تظهر النتائج اهتمامًا بالتنمية، خاصة فيما يتعلق بمقاومة الصدمات وصلادة السطح، حيث أظهر كلا الاختبارين نتائج متوافقة ، خاصةً عند (10٪) من DPET. في نفس الوقت ، كانت النتائج القصوى لقوة الانحناء عند (3٪). أظهر تحليل FTIR تفاعلًا كيميائيًا بين DPET و PMMA ، مما أدى إلى تحسين الخصائص بشكل كبير وجعل لها مجموعة واسعة من التطبيقات المتاحة.

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INTRODUCTION

The global rapid industrial enterprise pollution community growth has exponentially incremented the production and ingestion of plastics Chirag B,(2018). Incessant innovation explains that contemporary plastic production has been elevated by approximately (311 million tons) on a worldwide basis) Owusu,(2018). This development production and utilization of plastic have produced significant collective and environmental altercation in the jettisoning of their wastes. Some countryside has preferable solutions of waste administration for plastic while in other nations the plastic wastes terminus up with landfilling Owusu,(2018). The landfill process of plastic is of no monetary value; in this way, the waste can't be exploited. In the contemporary world, rational and more effective replacements are essential to efficiently administering plastic waste from the environment; recycling may be the best option Owusu,(2018). There are contrastive types of plastics; various plastics are not recyclable because of their composition and chemical properties. This plastic pyrolysis procedure (energy recovery) can be another option instead of recycling Anuar Sh.,(2017). The other kind of plastic can be transmuted into its indigenous monomeric situation by chemical or thermal processes Acosta,(2015) and Kikuchi,(2014). (PMMA) resin is the most widely utilized material for producing the dental plate since it combines good characteristics, such as lightweight and economical fabrication and unavailability of toxicity Carlsson G. E,(2010) and T. R. Meng,(2005). It's considered a kind of thermoplastic utilized globally in diverse applications, e.g., surface coating, electrically insulating material, and glassy all-weather layers. PMMA believes the fundamentals of a lot of materials tribe consisting of Plexiglas® and Lucite® Pereira,(2018). The multiple-use and cost production of it and preserve the environment from landfilling of PMMA. Although, PMMA has various disadvantages that demand to be addressed due to its unsatisfactory mechanical properties, such as fatigue defeat and impact resistance T. R. Meng,(2005) and Pratibha Y.,(2012). For instance, structure amendment to the composition, such as fillers, might improve PMMA mechanical properties Pratibha Y.,(2012) and T. K. Mowade,(2012). Previous studies appeared that glass fibers, much better than other types of fibers e.g., aramid carbon fibers, polyethylene, and nylon), could reveal poor adhesion with resin matrix Alla R. K.,(2013)- Uzun G.,(1999). It's appeared that the mechanical properties of PMMA composite be decided by bonding between the matrix and glass fiber reinforcement L. M. Goguta,(2006). To achieve an elevated level of adhesion between matrix and support materials, surface treatment of glass fiber with coupling agent previously mixing with resin matrix L. M. Goguta,(2006) and P. K. Vallittu,(1997). Numerous studies mentioned enhancement in mechanical properties of PMMA/silane such as flexural and impact strength, as fiber (G.F.s) P. K. Vallittu,1997- Prasad A. H.,(2011). Polyethylene terephthalate (PET) is thermoplastic polyester (semi-crystalline material), its characterized by a high level of strength, transparentness, and safety R. Lo´ pez-Fonseca,(2011). High molecular weight can be manufactured by subsequent polymerization level accomplishment in a solid-state at a low-grade temperature V. Sinha,(2010). This effective process to carry away all volatile impurities, such as water, free glycol, and acetaldehyde V. Sinha,(2010). The high molecular weight of PET. is necessary for enhanced mechanical properties like creep resistance, stiffness, and toughness while giving adequate flexibility to withstand bursting and fracture under pressure V. Sinha,(2010). The present work focused on the study of the effect of DPET and PMMA on the mechanical properties such as: Tensile strength, Charpy impact test, and Shore-D hardness. Also, study the extent of a chemical reaction between two materials using Fourier Transform Infrared Spectroscopy (FTIR) analysis.

DEPOLYMERIZATION OF POLYETHYLENE TEREPHTHALATE (PET)

PET is a globally utilized material-grade thermoplastic with a high level of impact and chemical resistance at ambient temperature Kamber,(2010). It's frequently used in injection-molded patron packaging merchandise like soft drink bottles and water Kamber,(2010). Even though PET does not cause chemical hazards to the environment, the increased usage of plastic cast away like, water bottles into landfills occasion a main environmental pollution dilemma Kamber,(2010), and Alzuhairi M,(2018). Moreover, recycling of PET assistances as a raw material in petrochemical commodities and energy. The quality of depolymerized PET can be guaranteed using chemical recycling; this process includes segmentation of the practical ester groups using reagents like, glycolysis, methanolysis, and hydrolysis Farahat,(2001) and Hussein A.,(2018). All of these can be produced at a high level of temperature with the presence of manganese acetate (catalysts) Chen,(2001), ethanoic acid, "lithium hydroxide, sodium/potassium sulfate Shukla,(2005), and titanium (IV) n-butoxide Pardal, F.,(2006)". Chemical recycling of polyethylene terephthalate is not oceanic practiced because of un convenient economics comparative to mechanical recycling and economical be of starting monomer Kamber,(2010). Consequently, the chemical recycling of PET is wide-scale implementation due to its positive effect on the environment and economically feasibleness Kamber,(2010).

EXPERIMENTAL

Materials and Method

Cold Poly-methyl-methacrylate (PMMA) (bulk density∼1.20 g/cm^3) works as matrix phase, and pure depolymerization polyethylene terephthalate (DPET) was prepared by bubble column reactor. Where, PET bottles cut into small pieces (3mm),washed, dried, and mixed with Ethylene glycol put in bubble column reactor (molar ratio = 4:1) In addition to, nano MgO (0.5% wt of PET) at (190-195 ºC),were used as catalyst, with nitrogen gas flowing from below to achieve bubbles, that play a major role in increasing mass and heat transfer. Thus; reducing reaction time (40 min). Full depolymerization will produce *monomer, dimer*, and trimer, and agglomerated. By distillation process, separates the liquid part from the solid. When the remaining part hardens, it is ground and then washed with distilled water for (0.5 hr). Then it is filtered and dried. DPET used to produce polymer composite, as shown in Figure (1) . PMMA was mixed with (1, 2, 3, 5, and 10) wt. % of DPET. Wax mold was used to produce (30) specimens were produced (twenty samples per mechanical test). FTIR analyses of the best percentage of the mechanical properties polymer can products were performed on KBr pellets.

Tensile Strength Test: The tensile properties were measured according to (ASTM D- 638) at a crosshead speed of 5 mm/min using INSTRON(M 3382, UK) universal testing machine.

Impact Strength Test: Samples for this mechanical test were made according to BS2000-ISO-1567 with sample dimensions (55 ×10 × 10) mm, with V-notch shape (2.5mm deep × 10mm width). Digital Charpy impact test machine was utilized at laboratory temperature, sample was fixed in horizontal position utilizing two beams (40 mm). A dip weight (0.5 J) was launched at the middle on the reverse side of the notch M. Gad,(2016) and N. S. Ihab,(2011).

Shore- D Hardness: is an instrument used to measure the surface hardness of rigid elastomers (thermoplastics and thermosets) utilizing an indenter force by graduate spring **Koch T**. The hardness measurement is calculated by permeation depth of the indenter under the influence (ASTM D2240) Koch T. The loading force of shore hardness D: ($0 \text{ N} \leq F \leq 44.5 \text{ N}$) with spherical cap ($0 \text{ mm} \leq h \leq 2.5 \text{ mm}$), with range value (0 – 100) Koch T. The mechanical properties of pure PMMA and PET, shown in Table (1).

Fourier Transform Infrared Spectroscopy (FTIR): is one of the analytical techniques that depend upon atoms of molecule vibration; an infrared spectrum results from passing infrared radiation over a sample. Some samples absorb the infrared radiation while other types of it are transmitted Jan A.(2017). Department of Materials Engineering/ University of Technology conducted FTIR used in this study.

RESULTS AND DISCUSSION

Average values, and statistically significant differences of flexural strength, impact strength, and shore D-hardness are shown in Table(2). The addition of different concentrations of DPET conspicuously enhances the flexural strength with increasing in DPET content. Increasing in DPET content especially, at (3%) wt improved the tensile strength of polymer composite. While as seen in figure (2), the impact strength showed contrastive results of tensile strength. Where, the improvement of impact strength increases gradually with DPET content, especially at (10%) wt, it has improved nearly twice as compared to (0%) wt content of DPET. Shore D-hardness appeared a corresponding results was obtained from impact strength, figure (2). FTIR analysis contains absorption of infrared photons, where the difference in bond vibrational depends on the state of the molecular Jan A.,(2017). Figure (3) illustrates FTIR of DPET, the finger-print distinctive vibration band of C=O in the range (1000-1727) cm^{-1}. While the stretching band, C-H refers to CH_3 group (methyl group) in the rang (3000-2900) cm^{-1}. The symmetric and asymmetric C-H stretching modes appear at (1300-1450) cm^{-1}. In-addition to, C-C bands appeared at (800-1000) cm^{-1} Ahmad S.,(2007). Besides, the PMMA spectrum Figure(4), appeared two slight bands at functional groups: C-H (2949.81-2993.80 cm^{-1}), and signal band of C=O at (1724.14 cm^{-1}). band at (2882-2951 cm^{-1}), double band of C=O ester carbonyl group at (1718 cm^{-1}), and at wave length (1111 cm^{-1}) asymmetrical stretching band of (C-O-C)was appeared. Also, at (727-881 cm^{-1}) indicating to C-Haromatic ring. Figure (6), shows FTIR spectroscopy for the best mechanical properties of a polymer composite that appeared at (10 wt%) of DPET content. The result presents broadband at wavelength (3000-3500) cm^{-1} of overlapping stretching of depolymerization. Therefore, the chemical reaction has existed during the curing process; this enhances the impact strength and shore-D hardness due to composite compositional morphology.

CONCULUSIONS

1. The bubble column technique provides the depolymerization process an excellent heat and mass transfer for effective reaction time.
2. Tensile strength, impact strength, and surface hardness have improved by the additives of the depolymerization polyethylene terephthalate (DPET).
3. FTIR spectroscopy appeared to be a chemical reaction between PMMA and DPET, reflecting on the improvement in blended morphology. This new mixture could be beneficial in adhesive, cosmetic materials and may be used as a front paint for cars.

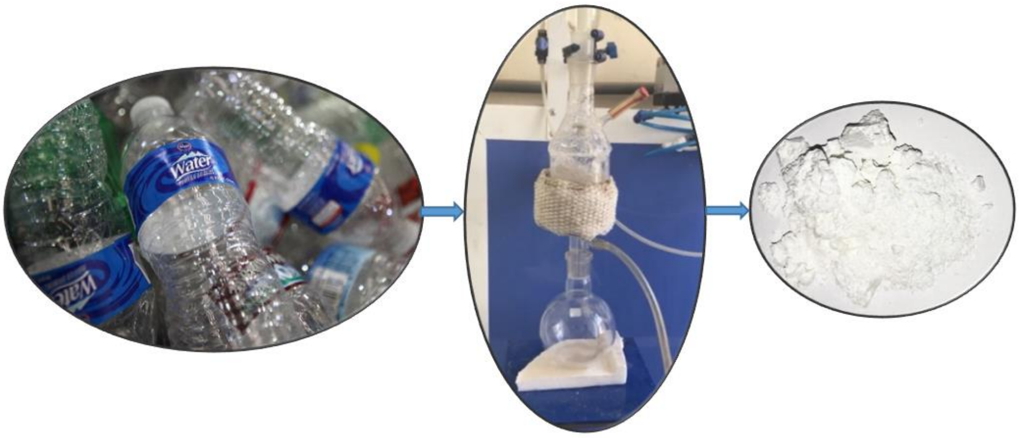

Fig. (1) Production of DPET from waste bottles (Hussein A.(2018)).

Table (1) Mechanical Properties of PMMA and PET.

Mat.s/Mechanical Properties	Tensile Strength(MPa)	Impact Strength (J/m)	Shore- D Hardness
PMMA	59	55	59
PET	61.7	4600 (4.6 KJ/m)	82

Table(2) Results of mechanical tests.

No.	DPET%	Tensile Strength(MPa)	Impact Strength(J/ cm^2)	Shore –D Hardness
1.	0	3.9	0.28	77.6
2.	1	4.15	0.30	80.4
3.	2	4.7	0.35	81.8
4.	3	5.6	0.40	83.4
5.	5	5.3	0.5	84.6
6.	10	5.3	0.65	87.2

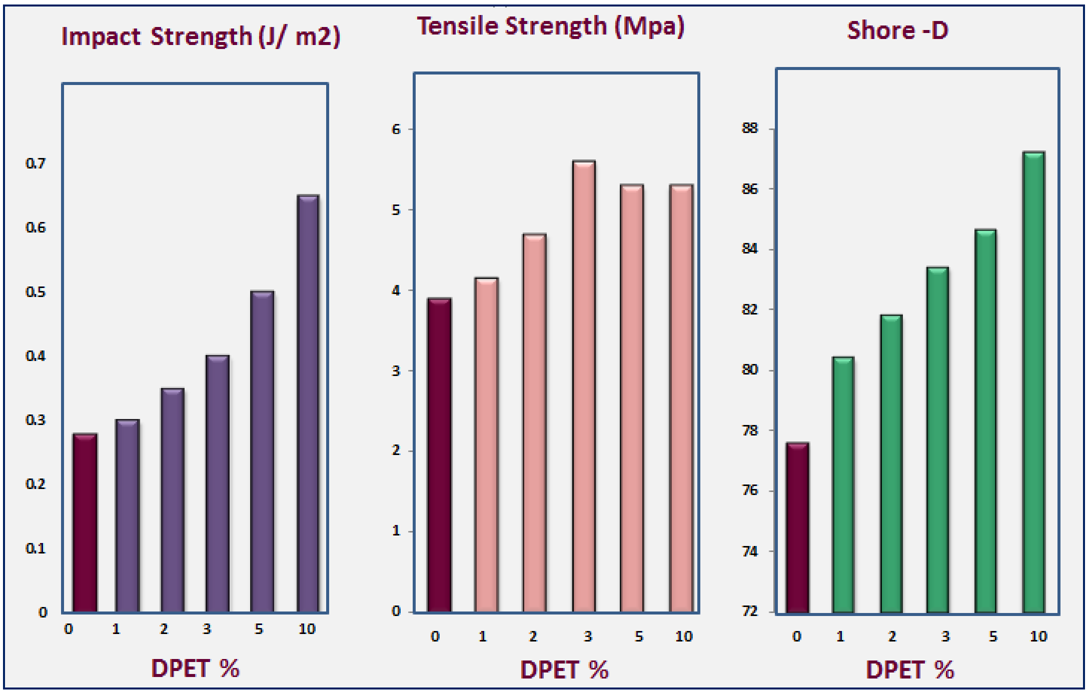

Fig. (2) Column chart of mechanical properties results.

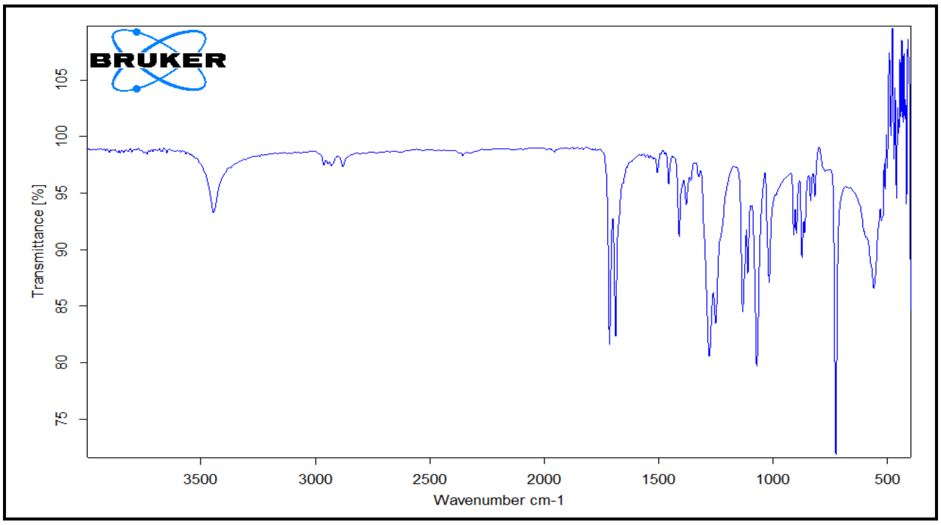

Fig. (3): FTIR test of DPET.

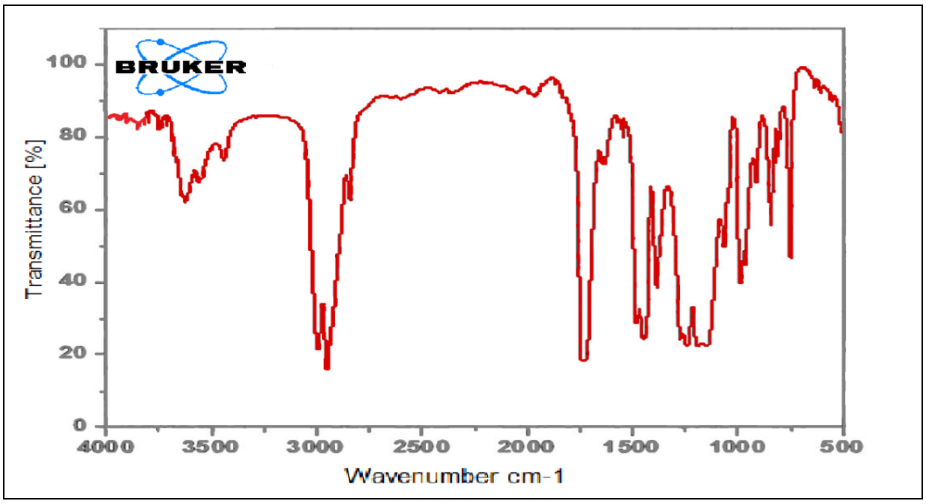

Fig. (4) FTIR test of PMMA

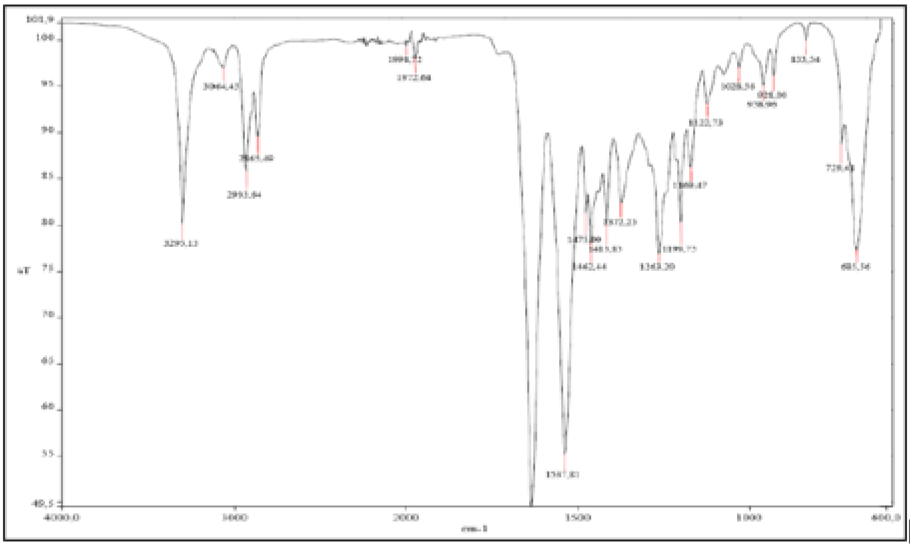

Fig. (5) FTIR test of Pure PET.

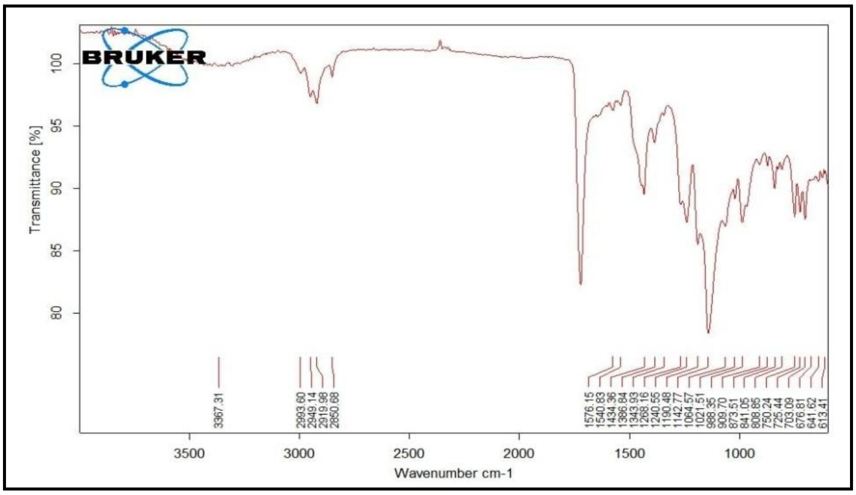

Fig. (6) FTIR of (10)% of polymer composite.

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