

Using the plastic wastes in fabrication of composite materials for different applications

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Abstract

This study suggests using the recycled plastic waste to prepare the polymer matrix composite (PMCs) to use in different applications. Composite materials were prepared by mixing the polyester resin (UP) with plastic waste, two types of plastic waste were used in this work included polyethylene-terephthalate (PET) and Polyvinyl chloride (PVC) with varies weight fractions (0, 5, 10, 15, 20 and 25 %) added as a filler in flakes form. Charpy impact test was performed on the prepared samples to calculate the values of impact strength (I.S). Flexural and hardness tests were carried out to calculate the values of flexural strength and hardness. Acoustic insulation and optical microscope tests were carried out. In general, it is found that UP/PVC composite exhibit the optimum values compared to UP/PET composite in all properties under test. From the experimental results, it can be concluded that the prepared composites from the waste could be utilized as precast or partitions inside the buildings with improved mechanical properties.

Key words

Plastic waste, polymer matrix composite (PMCs), polyethylene-terephthalate (PET), polyvinyl chloride (PVC).

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استخدام النفايات البلاستيكية في تصنيع مواد متراكبة متعددة التطبيقات

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الخلاصة

يقترح هذا البحث اعادة التدوير للمخلفات البلاستيكية لغرض استعمالها في تصنيع متراكبات ذات اساسات بوليمرية (PMCs) من الممكن استخدامها في تطبيقات متعددة. حضرت المواد المتراكبة بخلط راتنج البولي استر غير المشبع مع المخلفات البلاستيكية وقد استخدم نوعين من المخلفات اصبفت كحشوة بشكل قشور في هذه الدراسة شملت البولي اثيلين ترفثاليت (PET) والبولي كلوريد الفايثيل (PVC) وبكسوروزنية مختلفة (0، 5، 10، 15، 20 و 25) % نفذ اختبار صلادة نوع جاري على النماذج المحضرة لتحديد قيم مقاومة الصدمة لها. كما اجري اختباري الانحناء والصلادة لتحديد قيم مقاومة الانحناء والصلادة. اختبار العزل الصوتي والفحص بالمجهر البصري تمت على النماذج القياسية. بشكل عام، وجد ان المتراكب المدعم بمخلفات ال PVC يظهر قيم مثلى مقارنة بالمتراكب المدعم بمخلفات ال PET في جميع الخواص قيد الدراسة. ومن النتائج التجريبية يمكن الاستنتاج بان المتراكبات المحضرة من التدعيم بالمخلفات يمكن استخدامها كمصبوبات اولية جاهزة أو كقطع داخل المباني وبخواص ميكانيكية محسنة.

Introduction

Numerous studies predicted that supplies of oil, cracked into monomers for plastics production, will be depleted in either this or the next century [1]. World population, which surpassed 7 billion in 2011, is forecast

to exceed 9 billion by 2050. It is feared that the growing demand for resources will facilitate an increase in resource consumption and waste generation, contribute to deterioration of the natural environment and climate change. To

solve poverty, hunger, and environmental problems and achieve sustainable development in diverse ways while dealing with this increase in world population [2].

Plastics have become increasingly dominant in the consumer marketplace since their commercial development in the 1930s and 1940s [3]. Thermoplastics make up roughly 80% of the plastics produced today. There are hundreds of types of them and new variations are being developed but not all thermoplastics are recyclable [4]. Plastics are inexpensive, lightweight, strong, durable, corrosion-resistant materials, with high thermal and electrical insulation properties. The diversity of polymers and the versatility of their properties are used to make a vast array of products that bring medical and technological advances [5].

Polyethylene terephthalate (PET) is thermoplastic polymer widely used in application as diverse as textile fibers, films, bottles and other moulded products [6]. One of the main reasons for the widespread use of PET is their possibility of producing a number of different grades over a broad range of molecular weights in a single multiproduct polymerization plant [7]. Complicated and expensive procedures need to be operated in order for PET to degrade biologically [8]. Many researchers reported that in order to achieve successful PET recycling, PET flakes should meet certain minimum requirements [8, 9].

PVC is a universal polymer which can be processed into a wide variety of short-life or long-life products [10]. Its ability to be compounded with many additives to a wide range of flexible and rigid forms constitutes the major factor responsible for the versatility of PVC. Because of a low cost and the processability by a wide variety of techniques [11]. As a result of

increasing consumption of PVC-made products in recent years, the quantity of used PVC items entering the waste stream is gradually increased. Currently, there is a considerable public concern about the problem of plastic wastes, from which PVC has not escaped and the material or energy recycling may be a suitable way to overcome this problem [10]. At global level, the mechanical recycling of post-consumer and pre-consumer PVC wastes is 1.4 million tons in 2010 [12]. Calvin B. (2005) [13] researched a project in order to learn more about the quality of recycled plastics when compared to new material. The study was carried out by researching and learning about how the recycling process operates. The results of the experiment showed that most of the seven recyclable plastics could actually be used again as long as special care was taken to ensure that the quality of the recycled product was equivalent to that of the virgin material. It is clear that the price may be lower but after plastics are recycled they have been known to be lacking in some material properties. As a result, some plastics are mixed with others in order to gain better attributes for product applications. A larger recycling scale may work or products of PET and HDPE but the other categories namely, numbers 3-7 are recycled in moderation.

Rosana and Ricardo (2014) [14] develop a panel made from recycled plastics which is LDPE (low density polyethylene), BOPP (biaxially oriented polypropylene) and PVC (polyvinyl chloride) for housing and equipment, plastic materials from food, perfumery or cleaning packaging waste production from factories due to failures in sheet thickness or ink application. A comparison was made between their main technical properties and other conventional panels made

with wood particles; available in the panel does not swell under water, unlike conventional panels. The percentage of water absorption is lower than that of conventional panels. The flexural resistance is almost equal to that of an uncoated particle board. The density is higher than that of conventional panels made with wood particles.

Amir and Hamidreza (2014) [15] studied the use of recycled waste materials as modifier additives in asphalt mixes. The main purpose of this research was to investigate the effect of waste plastic bottles Polyethylene Terephthalate (PET) on the stiffness and specially fatigue properties of asphalt mixes at two different temperatures of 5 and 20 C. Likewise, the effect of PET was compared to styrene butadiene styrene (SBS) which is a conventional polymer additive which has been vastly used to modify asphalt mixes. Different PET contents (2–10% by weight of bitumen). Overall, the mix stiffness reduced by increasing the PET content. Although stiffness of asphalt mix initially increased by adding lower amount of PET. The stiffness of PET modified mix was acceptable and warranted the proper deformation characteristics of these mixes at heavy loading conditions. At both temperatures, PET improved the fatigue behavior of studied mixes.

Al-Tulaian et al. (2016) [16] discussed the effects of recycled plastic (RP) waste fibers on the flexural strength, flexural toughness and plastic shrinkage cracking characteristics of Portland cement mortar. Parameters investigated include fiber content and fiber length and tests performed include flexure and plastic shrinkage tests. Experimental results showed a substantial increase in flexural toughness, about 26 to 61 times, and a considerable increase in flexural

strength ranging from 6 % to 84 % of mortars reinforced with RP fibers compared to plain mortar. Test results also showed a significant reduction in width, and total area of plastic shrinkage cracks of slabs reinforced with an increased amount of RP fibers compared to control slabs without fibers.

The current study aims to recycle the plastic waste for reinforcement the polymer matrix and prepare the composite material with new modified properties as well as cleaning the environment from these solid pollutions.

Experimental work

Materials

Three types of materials were used to prepare composite materials. The matrix is polyester resin while the reinforcements included, Polyethylene-trephthalate (PET) and Polyvinyl chloride (PVC) respectively. Unsaturated polyester was used, supplied by Saudi Industrial Resins Limited Company (SIR) while Polyethylene-trephthalate (PET) in form of bottles and Polyvinyl chloride (PVC) in form of sheets were obtained from waste. The density of Polyester resin is 1.37 g/cm^3 while (PET) is 1.38 g/cm^3 and PVC is 1.35 g/cm^3 . Two types of wastes were used as reinforcement after the shredding process in flakes form.

Sample preparation

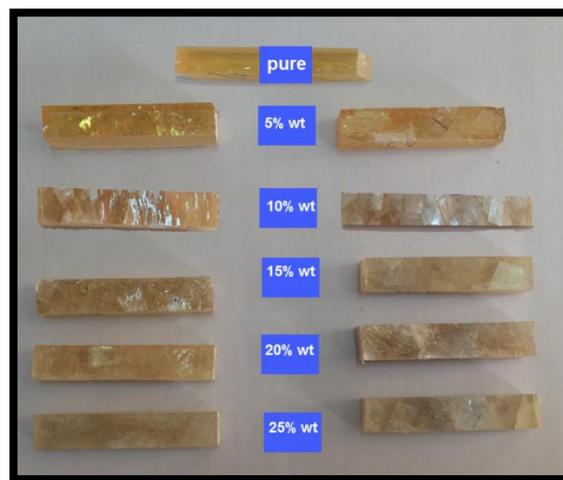
composites were manufactured from unsaturated Polyester resin with 2% of hardener then mixed homogenously with PET and PVC after selecting washing and shredding it, mould was made from glass with dimension of (25*25*1) cm. the outsides of mould were surrounded with silicon to prevent the leakage of resin from it. The reinforcements were in form of flakes as it shown in Fig.1.

The composites were prepared with various weight fractions (5, 10, 15, 20 and 25 wt. %) containing either PET or PVC flakes. After mixing all the constituents together the cast was put in the mould containing lubricant material to release inner sides of the

composite easily and left them for 1 hour in room temperature to complete the curing process. After fully solidification composites samples were cut according to ASTM and ISO specifications. The standard samples are prepared in Figs. 2 and 3.



Fig. 1: The form of both (PVC and PET) fibers after being shredded.



(a)



(b)

Fig. 2: The samples of composites reinforced with both (PVC and PET) flakes in different weight fractions (a) Impact (b) Flexural test samples.

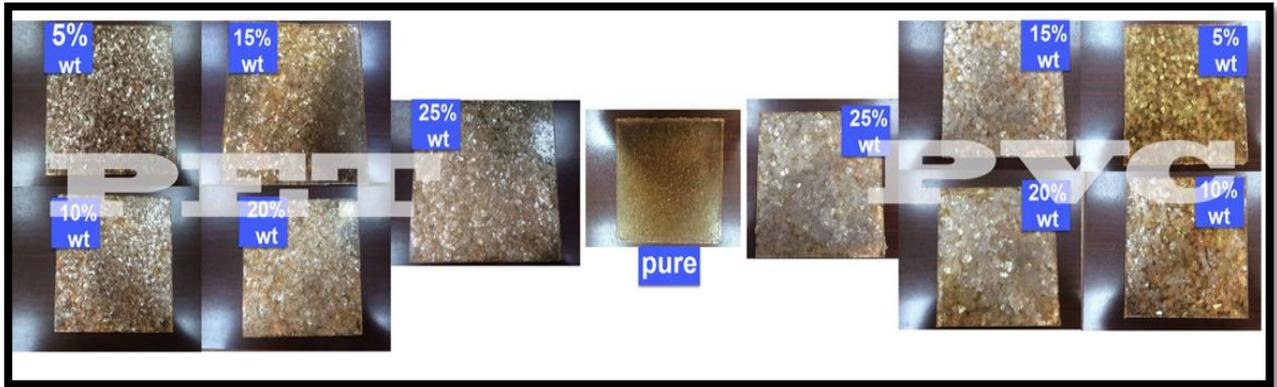


Fig. 3: The composite samples that were used for hardness and acoustic insulation test.

Test procedures

Impact test

Charpy impact test device used to figure the sample. The impact strength (I.S) is determined by the following equation [17]

$$I.S = \frac{U_c}{A} \quad (1)$$

where, I.S is the impact strength (kJ/m^2), U_c is the energy of fracture (kJ) and A is the cross sectional area of the sample (m^2). Fig. 2(a) shows the impact samples.

Flexural strength test

Flexural strength test was conducted on the prepared samples as shown in Fig.2 (b). Three points bending test method was used to calculate the values of (F.S) by applying the Eq. (2).

$$F.S = \frac{3Pl}{2bh^2} \quad (2)$$

where F.S is the flexural strength, l is the span (the distance between the two supports) and P is the applied load, s , b and h the length, the width and the thickness respectively.

Hardness test

Shore D hardness device (digital, type TH210, Italy) used to measure the values of hardness of the specimens illustrated in Fig. 3.

Acoustic insulation test

Acoustic insulation was measured using the domestically manufactured acoustic insulation device due to ASTM E-336. Fig. 3.

Results and discussion

This research investigates the effect of addition PVC and PET wastes on the mechanical properties (impact, flexural and hardness) of UP. Also, explains its effect on the values of acoustic insulation of UP. The effect of reinforcement with various weight fractions (5, 10, 15, 20 and 25 wt. %) for both (PVC) and (PET) as waste materials were determined in this work.

Charpy impact test was carried out on all composites samples (un-notched). Fig. 4 demonstrates the relevance between the impact strength with the weight fractions of the two types of wastes.

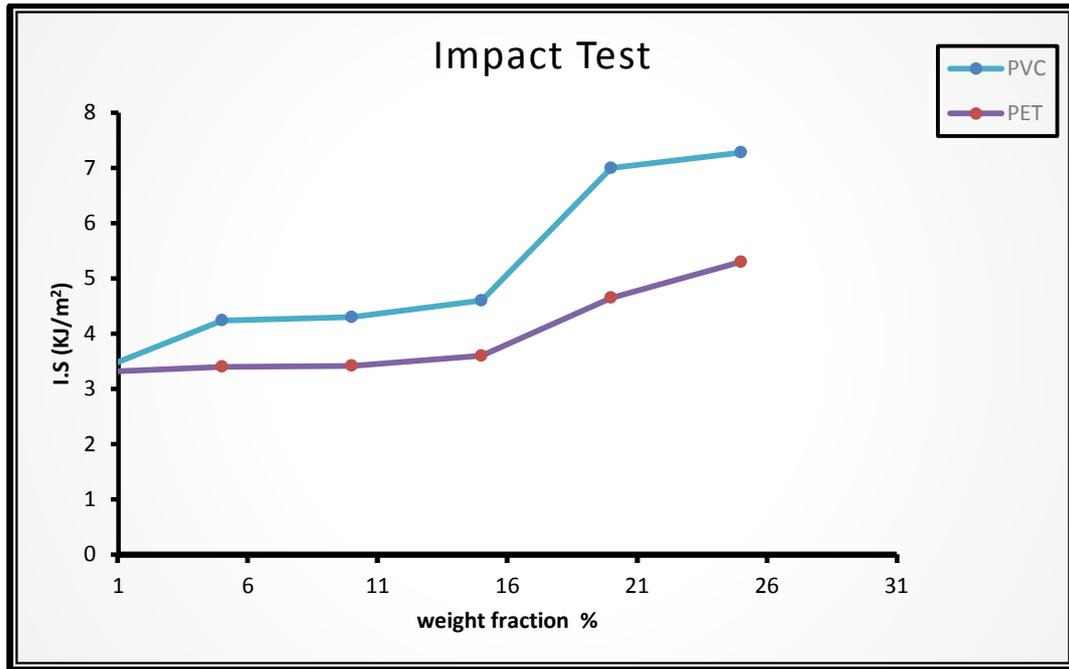


Fig. 4: Effect of wt% of waste on the impact strength values of the composites.

It is noticed that the composite reinforced with (PVC) as reinforcement has the highest value of (I.S). The reason is due to the material ability of PVC to absorb energy before the fracture more than PET.

The increment ratio of impact strength of composite containing (PVC) reinforcement is 120.6 % but equal to 60.6 % for the PET composite of 25 wt.% compared with the pure resin. Also, the hardness test (shore D) with varies weight fraction of both (PVC) and (PET) was carried out. Fig.5 demonstrate the hardness values of all specimens.

In Fig.5, the curves show the dependence of Shore D hardness on the content of both composites as a function of weight fraction of waste added. This curve could be divided into three regions corresponding to the

behavior of material the first is the low additive content region where the hardness follows a gradual decrease with increasing the content of both (PVC and PET). The composites exhibit low ductility in this region, so it can be named the brittle region. The second region is the brittle-ductile transition when the additive content increases from (5 to 15) % of the two wastes where the hardness greatly influence by the content of the additive. When the content exceeds 15%, the composites exhibits higher toughness and the effect of additive lead to decrease the hardness values and becomes less compared with previous ratios, this represents the ductile region (region 3). Previous study [18] indicated to the same regions as shown in Fig.5.

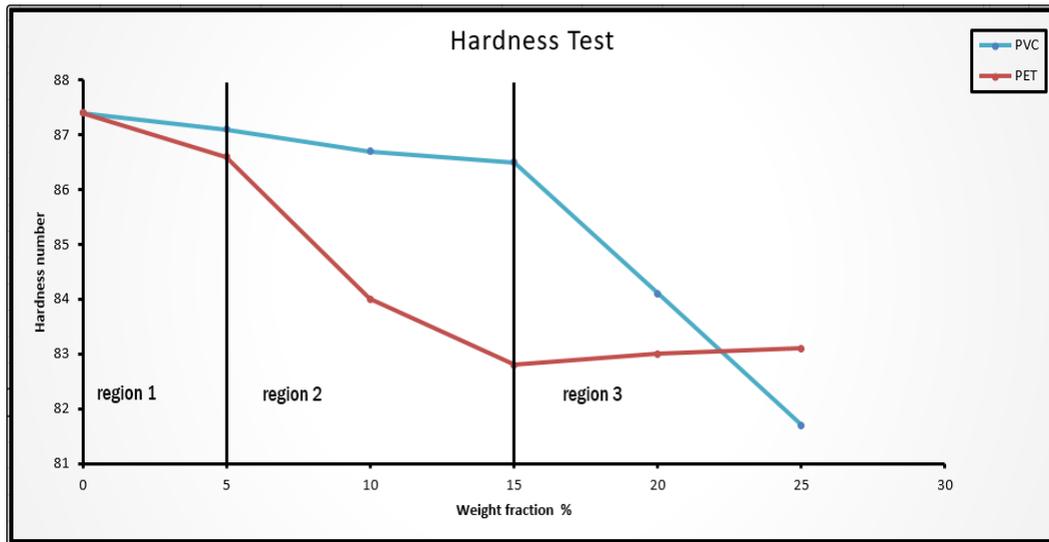


Fig. 5: Hardness number of the composites.

Flexural strength test is one of the tests that were carried out. Fig.6 illustrate the relevance between the flexural strength (F.S) and weight fraction of waste content. It is clear that the effect of addition of the ratios (5 and 10 wt.%) is not positive on the

values of (F.S). It can be noticed that PVC waste imparts higher value of F.S of 15, 20 and 25wt. % compared to PET. This means that the composite reinforced with PVC waste resists the flexural stresses more than that reinforced with PET waste.

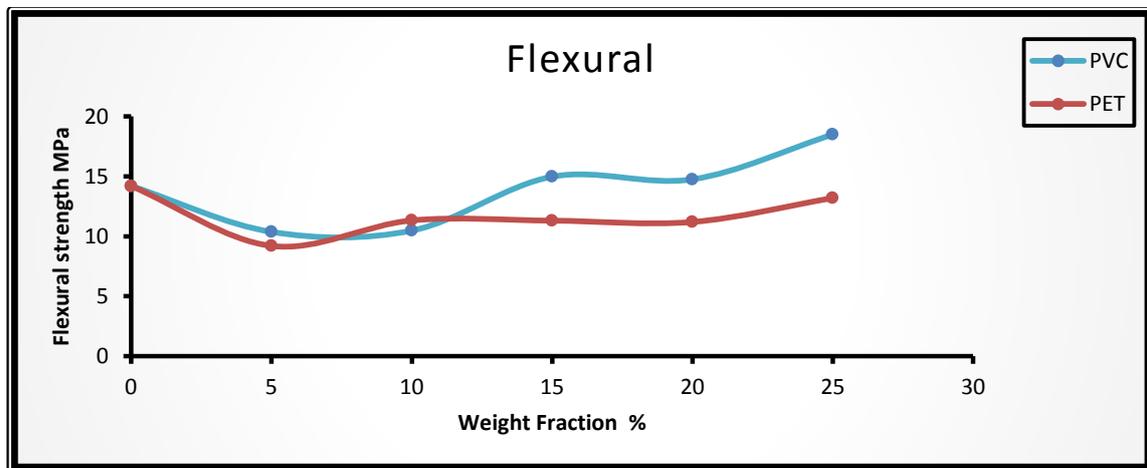


Fig. 6: Flexural strength behavior of the composites.

The main factors in calculation of good acoustic insulation properties are the equivalent sound absorption and sound level. Figs. 7 and 8 represent the relation between the values of sound levels with frequency of both composites. It can be found that the two composites with 25 wt. % record the optimum values of sound insulation and the difference between them is

little. This result can be considered as encourage factor to use these waste for manufacturing sound insulating materials. This behavior clearly exhibits as shown in Fig. 9 which shows the relation among the sound level with the weight fractions of the prepared composites compared to the pure polymer and space when it used for acoustic insulation.

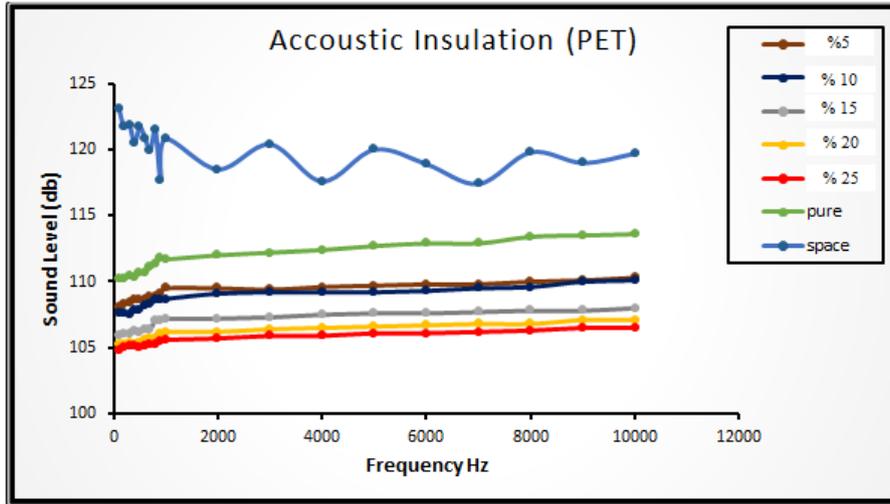


Fig. 7: The relation between sound level and frequency for composite reinforced with (PET) for different weight fraction.

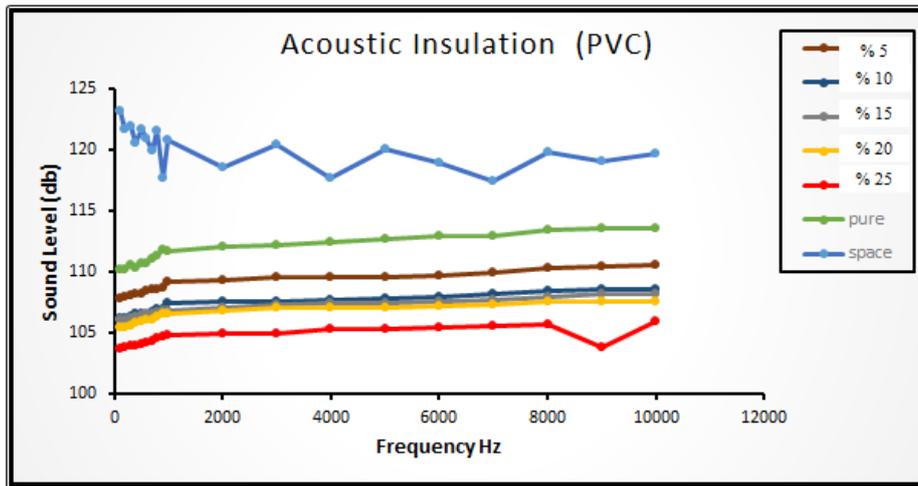


Fig. 8: The relation between sound level and frequency for composite reinforced with (PVC) for different weight fraction.

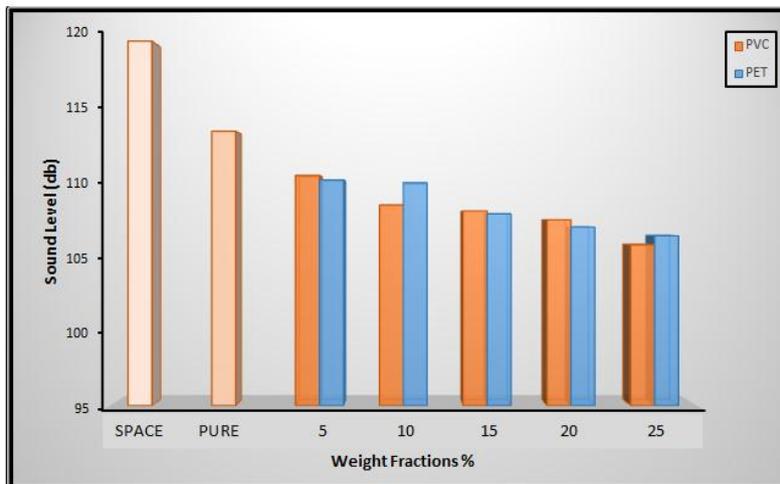


Fig. 9: Comparison between sound level intensity for composites reinforced with (PVC and PET) with different weight fractions.

Optical microscope test

Fig.10 shows the optical micrograph of the fracture surface of (a) the pure polymer (b) the composite reinforced with PVC waste and (c) the

composite reinforced with PET waste after subjected to impact loading. Fig.11 shows topographic images of the prepared samples.



(a) UP (pure)

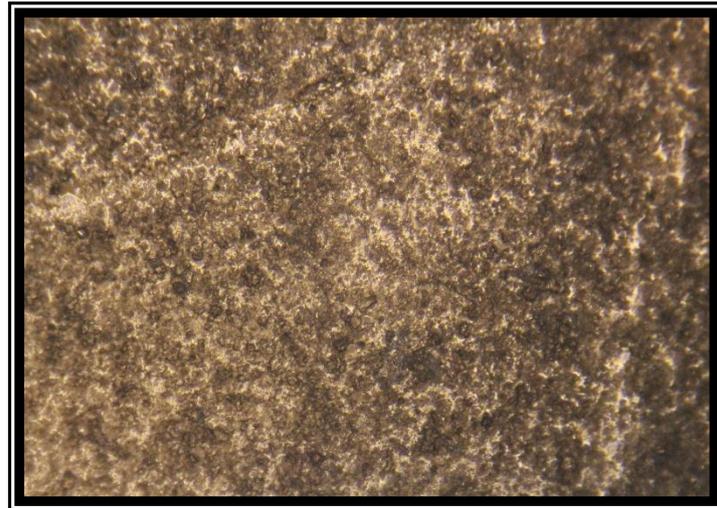


(b) 25wt. % PVC waste

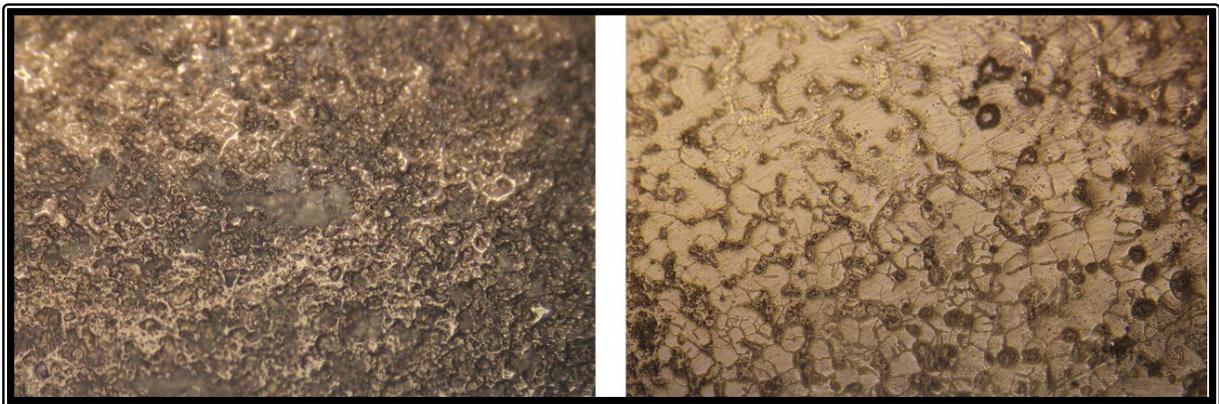


(c) 25 wt. % PET waste

Fig.10: Optical micrographs of the fracture surface of the composite samples (a) the pure unsaturated polyester (b) the composite reinforced with PVC waste (c) the composite reinforced with PET waste (magnification=10 \times).



(a) UP (pure)



(b) The composite reinforced with PVC waste. (c) The composite reinforced with PET waste.

Fig.11: Topographic images of the prepared samples for (a) the pure polymer (b) the composite reinforced with 25 wt. % of PVC waste and (c) the composite reinforced with 25 wt. % of PET waste.

Conclusions

It can be concluded that PVC waste imparts higher impact strength compared to PET waste in all weight fractions reinforcement. It is found that the hardness of the two types of composites under work decreased with increasing the weight fraction of each PVC or PET. The flexural strength values of composite decrease at the percent 5%wt. of each type of an added waste but return to increase with (10, 15, 20 and 25 wt.%). Finally, it is observed that the ratio 25%wt. of PVC or PET gives the optimum acoustic insulation compared to pure polymer and other weight percent of the prepared composites.

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