Thermo-Chemical Behavior of Epoxy Composite (EP/PVC) Reinforced by Addition of Scrap Tires

Raghad U.Abass
Applied Sciences Department, University of Technology /Baghdad
Email:ragad_20042000@yahoo.com

Received on:12/6/2016 & Accepted on:29/9/2016

ABSTRACT
The high performance and unique utilization properties applied by designers according to improvement of thermal and mechanical products were reinforced by particulate materials. The present study deals with the preparation of a composite system (EP/PVC). afterward the estimation of thermo-chemical behaviour of epoxy composite (EP/PVC) reinforced by addition of micro-fillers particulate of waste scrap tires (WST). Three different sets of epoxy-PVC composites are fabricated with addition of 0, 0.25, and 0.4 wt% of WST particulates. These composites have been prepared and both chemical reactivity absorbance and thermal conductivities are achieved. From results it appeared that a decreasing in thermal conductivity values about 55 % for 0.25wt % for a micro-WST of epoxy composite system, of 0.4wt. %recorded decreasing of thermal conductivity at88 %when compared to epoxy composite system (EP/PVC). The results show that the (WST) micro-fillers particles show an insulation polar behaviour at 0.4 wt. % at which a random behaviour in thermal conductivity is recorded .In addition to an experimental examination of chemical activity absorbance for both composite system before and after additive of micro-filler particulate of waste scrap tires (WST) in different soaking medium (normal and acidic solutions) and different residence times (0-120 hrs) respectively. The results proved that an improvement chemical activity occurred for optimum sample no. 3 of (2.5/ .4 + .4 (EP/PVC + WST) that have minimum loss in weight as (0.001) under both soaking medium (100% H_2O, 10% H_2SO_4) rather than base composite system (EP/PVC) and other improved one of .25 wt. % from WST of (0.01 – 0.05) respectively.
Keywords: (EP/PVC) matrix, thermo- chemical activity, additive of micro- filler particulate, waste scraps tires.

INTRODUCTION
The composite materials have superior properties than other materials attributing to their utilization properties as (tensile strength ,flexural distortion and impact resistance); in addition to their resistance to fatigue that enable these structural designs to be more applicable. Epoxy resins, are very stable on curing, with no volatile products in the presence of a volatile solvent. These types of composite systems are applied in a variety of electronic components attributing to superior moisture resistance and thermal stability, in addition to their economic aspects. They have recently found uses in intelligent materials and would help to reduce consumption of petroleum products as well [1- 5].Also has found wide applications in industries as surface coatings, structural adhesives, printed circuit boards, insulation materials for electronic devices, and advanced composites matrices. Nevertheless, curing reactions of epoxy with its hardeners are generally irreversible, so that cured epoxy can hardly exhibit crack remendability as a result of lack of the ability of recombination of broken molecules. The epoxies groups can react with traditional curing agent like anhydride to form an epoxy network, providing the material with outstanding mechanical properties and thermal resistance as usual. Meanwhile, the furan groups can react with maleimide to introduce thermally reversible Diels-Alder (DA) bonds into the epoxy

https://doi.org/10.30684/etj.34.6B.6
2412-0758/University of Technology-Iraq, Baghdad, Iraq

network. Eventually, the molecular networks in the cured material are comprised of inter-monomer linkage. Reinforced composites system by particle fillers, are applied basically for improvement ductility and reduced modulus of final materials. The limitation deformation in these particles was reducing the cost of prepped composites. Several Nano-ceramics materials have high utilization properties such as (superconductivity, magnetic, and piezoelectric) at low applied temperatures, which make them more applicable in different composite systems. In spite of their major disadvantage brittleness property [6, 7].Recently many applications of ceramic composite systems as communication, advanced aircraft, satellites, and high density electronics were appeared [8]. These composites systems are flammable according to their natural chemical structure which requires high flame retardency. Therefore composites materials requiring ideal thermal conductivity and low thermal expansion in order to be ideal applicable in these fields [9,10].

A Shojaei et al. [11] have determined the thermal conductivity of rubber-based composites friction materials. Where application of many fillers as copper, brass chips, and aluminum chips afterword was studied the effect of addition of these fillers on the thermal conductivity of final composites , they gets that aluminum chips filled composites have maximum thermal conductivity. On the other hand, Wong et al. [12] have studied many applicable properties as elastic modulus, thermal conductivity, and thermal expansion coefficient for composite epoxy systems filled with silica and alumina particles, then he got final applicable models as Agari's models. Another studied achieved by Hansen et al [13], Penget S. [14], Tavman C.L. [15], Choy et al [16] on heat conductivity property in composite system, these studies were focused on the thermal behaviour of neat polymers only not of their composites. Many numerical and analytical studies were achieved on polymer filled ceramic particles systems in order to reach an ideal model system [17, 18, 19], where Progelhofet et al [20]has been studied many models and methods that determining thermal conductivity of composite systems .Nielsen [21] also investigated thermal conductivity property for many kinds of polymer reinforced by different particles then have been investigated their final utilization properties. Nagai et al [22] have studied the modification form of Al_2O_3/epoxy system and AlN/epoxy system. SanadaI. [23] Studied both microstructure and thermal conductivity composite systems reinforced by Nano and micro particles. Also another investigation were achieved to study the fracture behaviour of boron nitride (BN) composites reinforced several types of fillers as carbon and ceramic fibres, both strength and toughness of these systems were studied toothier effectiveness of characteristics properties for fibre/matrix interface [24, 25, 26].There are many difficulties found in recycling of scrap tires because of their non-desired results emissions or final wastes. Therefore a potential to use large volumes of shredded waste tires as fillers in polymer composites systems. Fine scrap tires of smaller particle size have a good option for these systems. These types of fillers make them an ideal material for many applications such as moulding supported parts. Many authors[27, 28] were studied their cryogenic property at room temperature by manufacturing moulds with 40% wt of ground scrap tires and 60% of polypropylene on the final ultimate tensile strength. Falak O. Abas et al has been **s**tudied the comparison of different ceramic filler on mechanical and thermal properties of glass, carbon, Kevlar / polyester composites [29].

This research has been objective to study the thermo-chemical properties for the composite system (EP/PVC) reinforced by addition of scrap tires (WST) micro-fillers, where different amounts of ground waste tires are used. Estimate their effectiveness on thermal and chemical properties of epoxy composites by comparison of results. Preparation of a new composites using waste scrap tires (WST) as reinforcing active particles to support the thermal and chemical stability of epoxy system. Characterization and optimization of these PVC-EP/ WST active systems then investigated the effect of WST additives on both thermal and chemical stabilization.

Materials and Methods:
Materials:
Matrix Material
Epoxy LY 556 resin, was used in this study the corresponding hardener was (HY 951), they were mixed at mixing ratio (3:1) wt. %. Epoxy applied has low density at (1.1 gm. /cc), (0.363W/m. K) thermal conductivity respectively [32, 33].

Waste tire rubber
Waste tires rubber presents the discarded automobile waste tires that are collected from the stockpiles of automobile waste tires in Baghdad. It consists of approximately 50% chips waste tires (13-100mm) size, and 50% grounded waste tires of (0.14-13m m) size. Briefly the waste tires are grinded manually after collection. Table (1) presents the measured physical and mechanical properties of waste tires rubber .A sample of waste tires is shown in Figure (1) [40, 41].

Table (1) Physical and mechanical properties of waste tires rubber

Properties	Values
Compacted Density (Kg/m3)	745
Shape of particles	Grounded waste tires < 250µm particle size
Color	Black
Water absorption 24 h (%)	0.01
Compressive strength	Weak and poor
Tensile strength (PSi)	7000
Activity	Hydrophobic and Non active

Figure (1) Waste tires rubber

PVC material
White hard thermoplastic powders of (< 100 µm) particle size locally available; the density is 1.38 g/cm3. Be suitable for making objects satisfying regulations concerning food products and

objects in contact with food. Thermal properties: has a vitreous transition temperature lying between 75 and 80°C, i.e. at ambient temperature it is rigid and above 90°C it is rubbery (low resistance, high distortion), decomposes in a flame, used as coupling and support agent for epoxy resin in composite system (EP/PVC) [37].

Methods:

Standard process for epoxy composite (EP/PVC) preparation

Mix 3 parts of a primer resin to 1 part of (B) activator. Due to the high viscosity of the product manual mixing is not recommended. All mixing should be performed with 400-600 rpm power drill and the mixing attachment provident. Use low speed and keep mixing blade down in the product to avoid entrapping air in the mixture. Start by premixing component (A) primer resin to compensate for any settling which may have occurred. Then empty the entire content of component (B) primer activator in to component (A) primer resin and mix for a minimum of 15 min after a uniform appearance is first obtained. Pay special of the contained to insure complete mixing, then different types and concentration of additives are used as polyvinylchloride(PVC)(0, 2.5, 0.4 g/g) respectively with continuous mixing for 10 min then these prepared samples are improved by addition of micro-fillers as waste scrap tires (WST) particulate in the next step.

Improved Composite Fabrication

The composites system (EP/PVC) is then improved by cold mixing with Micro-sized WST average size of < 250 μm all contents mixing should be performed with 400-600 rpm power drill and the mixing attachment provident. Composites of three different compositions 0, 0.25, 0.4 wt. % of WST are made moulds by manually techniques to prepared three active systems with different micro-particle active components. The moulding samples are left cure at lab temperature 35^{O}c for about 24 hours after which the cups are broken and samples are released and table (2) estimate the design composition used in preparation of improved composite system (three- component).

Table (2). design samples composition (for WST filled EP/PVC composite)

Sample no.	Epoxy (EP) g	Polyvinylchloride (PVC) g	Waste scrap tires (WST) g
1.	2.5	0.5	0
2.	2.5	0.25	0.25
3.	2.5	0.4	0.4

Techniques used in this work

Different techniques were applied in this work as chemical resistance- activity characterization and thermal conductivity property to determine the thermo-chemical property of improved epoxy composites.

The absorbance character is evaluated using accurate weighed of samples as 0.5g from composites. Two different chemicals in aqueous solution were used: H_2SO_4 10% v/v aq H_2O 100% v/v aq respectively. For each particle size category from WST three compositions have been studied: 0, 0.25, and 0.4 % weight of WST. The samples are immersed in aqueous chemical solutions (100% H_2O, 10% H_2SO_4) at laboratory temperature 35^{O}c for 120 hours in order to reach point of equilibrium. At the end of this period, the test piece is taken out and the adhered liquid is rapidly removed by blotting with filter paper. Afterwards the swollen weight is immediately measured. The swelling ratio is defined as:

$$\mathbf{R = (W_1\text{-}W_0)/W_0}$$

Where W_0 is the weight of the test piece before swelling or absorbance and W_1 is the weight of the swollen test piece after time (t) of immersion.

Thermal characterization is performed by means of using Lee- disk kocyigit Electron DC 0-30 volt and 6 Am USA instrument for prepared samples of (1 cm thickness and 3cm dia.) dimensions under the condition of lab (35C°), the prepared composite system applied between two copper disks then heating these disks afterward reading the change in temperatures by applying accumulated temperature load until failure of specimen occurred from (increasing temperature) (T1, T2, T3), calculator the expansion factor and thermal conductivity by the use of two equations below to calculate the thermal conductivity coefficient (K):

$$e = P/\pi r\ [r\ (T1+T3) + 2\ (d1T1+0.5ds\ (T1+T2) + d2T2+d3T3] \quad ..(1)$$

$$K = eds\ [T1+2T1\ (d1+0.5ds)\ /r+T2ds/\ r]\ /\ (T2 - T1) \quad ...\ (2)$$

Where:

e = loss in heat per unit area in (w /cm2. c°).

P = supplied power in (w).

r = radius of disk in (cm).

d1, d2, d3 = thickness of disks in (cm).

ds = thickness of specimen in (cm).

T1, T2, T3 = measured temperatures of disks no., 1, 2, and 3 in (c°).

K = thermal conductivity in (w / cm .c°).

Figure (2) Lee disc thermal conductivity instrument

Results and Discussions:

Ground scrap tires as micro-filler on (EP/PVC) composite

Figure 3show that the epoxy/PVC composite, with ground scrap tires characteristics the effective thermal conductivity (*K*) of the composites. Figure 2presents the variation of *K* with the WST content. It is observed that the *K* of epoxy composite system is about 0.009W/m.K and it gradually decreases to 0.001W/m.K with an increase in WST content. A dropped in thermal conductivity values occurred as88 %, when the WST content increases to 0.4 %wt. In this work, different weight fractions of WST micro-filler are added into epoxy- PVC system to observe its effectiveness on resultant thermal conductivity. It is noticed that due to the decrease of *K* the thermal insulation capability of epoxy- PVC improves [37, 38].

Swelling Measurements

Figures(4, 5) show the swelling measurement of the composites where the EP/PVC+WST ratios were different at (2.5 wt.% for EP),(0.5 , 0.25, 0.4 wt.% for PVC), and (0, 0.25 , 0.4 wt.% for WST) respectively. High concentrations of peroxide (>1%) lead to crosslinking reactions and afterward the toughness of samples and estimate the chemical activity- resistance for the improved and non-improved prepared composites. The results show that an improvement in chemical activity occurred for optimum sample no. 4 of (2.5/ .4 + .4 (EP/PVC + WST) that have minimum loss in weight as (0.001) under both soaking medium (100% H_2O, 10% H_2SO_4) rather than base composite system (EP/PVC) and other improved one of .25 wt. % from WST of (0.01 – 0.05) respectively. The high chemical resistance and high polar groups for applied micro- filler WST that caused an improvement in chemical properties [25, 28].

CONCLUSION

1. Waste scrap tires WST used as micro-filler in an epoxy system to be an optimal method to reuse large volumes of shredded tires afterward improve their chemical resistance of final composite system (EP/PVC) at different chemical aqueous solutions exposure.
2. Optimum sample that give excellent thermo- chemical properties is sample no. 3 of (2.5/ .4 + .4 (EP/PVC + WST) design weight ratios.
3. The measured values of effective thermal conductivity are obtained for different weight fractions of WST micro-fillers. Incorporation of WST results in reduction of thermal conductivity of epoxy system about 88 % and thereby improves its thermal insulation capability.

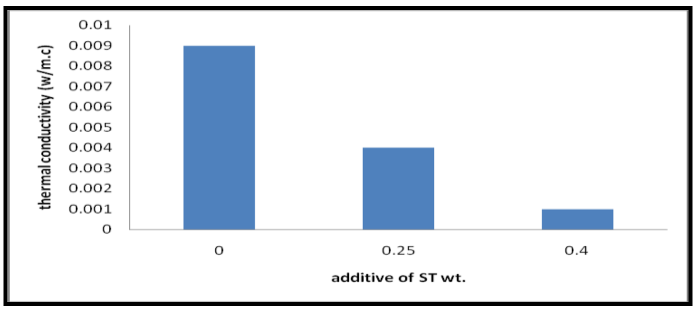

Figure (3) estimate the effect of micro- filler particulate of WST on thermal conductivity of improved EP/PVC system.

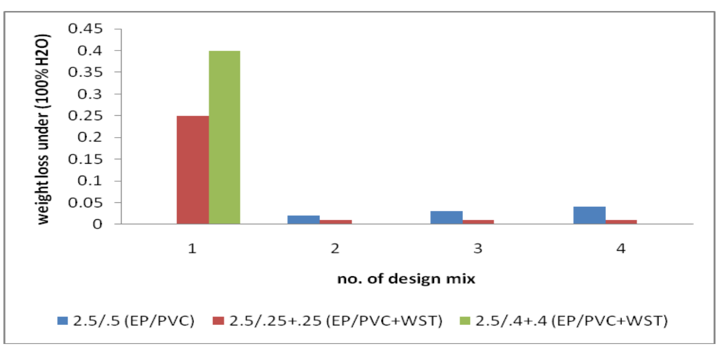

Figure (4). Estimate the effect of micro- filler particulate of WST on chemical resistance of improved EP/PVC system under normal solution (100% H_2O).

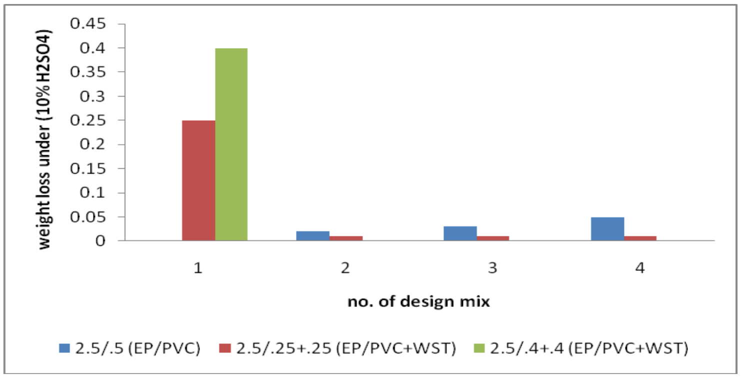

Figure (5) estimate the effect of micro- filler particulate of WST on chemical resistance of improved EP/PVC system under acidic solution (10% H_2SO_4).

REFERENCES

[1]. David R.CRC Handbook of Chemistry and Physics, CRC Press Inc, 2009.

[2]. Arun Kumar Rout , Alok Satapathy , Ashok Kumar Sahoo, Dipak Kumar Jesthi ; 5th International & 26th All India Manufacturing Technology, Design and Research Conference, Guwahati, Assam, "A Study On Evaluation Of Mechanical And Thermal Properties Of Rice Husk Filled Epoxy Composite"; December 12th–14th, 2014

[3]. Gracia, D., Lopez, J., Balart, R., Ruseckaite, R.A. and Stefani, P.M. (2007), Composites based on sintering rice husk-waste tire rubber mixtures, Materials and Design, Vol. 28, pp.2234-2238.

[4]. Mamunya Y.P., Davydenko V.V., Pissis, P. And Lebedev E.V., (2002), Electrical and Thermal Conductivity of Polymers Filled with Metal Powders, J. European Polymer, Vol. 38(9), pp.1887–1897.

[5]. Maries Indicula, Abderrahim Boudenne. Thermo-physical properties of natural fiber reinforced polyester composites. Composites science and technology, 66, (2006), 2719-2725.

[6]. DilekKumlutas, Ismail H Tavman. Thermal conductivity of particle filled polyethylene composite materials'Composites science and technology, 63 (2003), 113-117

[7]. Assael M T, Antoniadi K D s. "The use of the transient hot-wires technique for measurement of the thermal conductivity of an epoxy-resin reinforced with glass fibers and/or carbon multiwall nanotubes", 68, (2008), 3178-3183

[8]. Bozee Y LE ,Kaang S , Hine. P J "The thermal –expansion behaviour of hot –compacted polypropylene and polyethylene composites". Composites science and technology, 60, (2003), 333-344

[9]. Dvir H., Gottlied M. Optimization of a flame–retarded polypropylene composite. Composites science and technology', 63 (2003), 1865-1875

[10]. Rohatgi P K, gupta N. and Simon Alaraj. "Thermal expansion of aluminium-flyash chemosphere composites synthesized by pressure infiltration technique". Journal of composite materials, 40, (2006), 1163-1174

[11]. Shojaei A., Fahimian M. "Thermally conductive rubber based composite friction materials for rail road brakes-Thermal conduction characteristics". Composites science and technology, 67, (2007), 2665-2674

[12]. Wong C. P, Raja S. Bollampally, Thermal Conductivity, Elastic Modulus, and Coefficient of Thermal Expansion of Polymer Composites Filled with Ceramic Particles for Electronic Packaging, j. of Appli., Polymer Sci.,(2009): pp.3396–3403.

[13]. Hansen D. and Ho C., Thermal conductivity of high polymers, J. of Poly. Sci. Part A, 3(2) (2005): pp. 659–670.
[14]. Peng S. and Landel R., Induced anisotropy of thermal conductivity of polymer solids under large strains, J. Appl. Poly. Sci., (2007): pp. 49–68.
[15]. Choy C.L., and Young K., Thermal conductivity of semi-crystalline polymers– A Model, J. Polymer, (2006): pp. 769–776.
[16]. Tavman I., Thermal anisotropy of polymers as a function of their molecular orientation, experimental heat transfer, fluid mechanics, and thermodynamics, Elsevier (2010): pp. 1562–1568.
[17]. Progelhof R.C, Throne J.L. and Ruetsch R.R., Methods of predicting the thermal conductivity of composite systems, J. Polymer Engineering and Science, 16(9) (2008): pp. 615–625.
[18]. Geon-Woong Lee, Min Park, Junking Kim, Jae Ik Lee and Ho Gyu Yoon, Enhanced thermal conductivity of polymer composites filled with hybrid filler, Composites, (2006) : pp.727–734.
[19]. Wenying Zhou ,Caifeng Wang, Tao Ai , Ke Wu, Fenjuan Zhao and Hang zhou Gu, A novel fiber-reinforced polyethylene composite with added silicon nitride particles for enhanced thermal conductivity, Composites, (2009):pp. 830–836.
[20]. Progelhof R.C., Throne J.L. and Ruetsch R.R., Methods of predicting the thermal conductivity of composite systems, J. Polymer Engineering and Science, 16(9) (2007): pp. 615–625.
[21]. Procter P., Solc J., Improved thermal conductivity in microelectronic encapsulates. IEEE Trans on Hybrids Manuf. Technol, (2009): pp. 708–713.
[22]. Nagai Y., Lai G.C., Thermal conductivity of epoxy resin filled with particulate aluminum nitride powder, J. Ceram SocJpn, (2006): pp. 197–200.
[23]. Kazuaki Sanada1, Motoki Kurachi1 and YasuhideShindo, Microstructure and thermal conductivity of polymer composites with nano and micro fillers.
[24]. Wenying Zhou, Shuhua Qi, Qunli An, Hongzhen Zhao and Nailiang Liu, Thermal conductivity of boron nitride reinforced polyethylene composites, Materials Research Bulletin (2007):pp.1863-1873.
[25]. Cameron G. Gofer, James Economy, Youren Xu and Avigdor Zangvil, Edgar Lara- Curzio ,b Matt K. Ferberb & Karren L. Moreb, Characterization of fiber/matrix interfaces composites with a boron nitride matrix, Composites Science and Technology, (2005):pp. 967-975.
[26]. Toldy, A.; Anna, P.; Csontos, I.; Szabó, A.; Marosi, Intrinsically flame retardant epoxy resin - fire performance and background – Part I, Polymer Degradation and Stability, 92 (12), 2223 (2007).
[27]. Liu, H., S.; Richard, C., P.; Mead, J., L. Development of Novel Applications for using recycled rubber in thermoplastics. Chelsea Center for Recycling and Economical Development Technical Research Program (2000).
[28]. Liu, H. S.; Mead, j. l.; Stacer, R. G.; Process development of scrap rubber/thermoplastic blends.Chelsea Center for Recycling and Economic Development 36 (2001).
[29]. Falak O. Abas, Raghad O. Abas, Sarmad I. Ibrahim, “A Comparison Study of Different Ceramic Filler on Mechanical and Thermal Properties of Glass, Carbon, Kevlar / PolyesterComposites”, engineering and technology journal , vol.28, no.12,,pp.2469- 2479, 2010.