Investigating the Effect of Weight Ratios on Some Mechanical and Thermal Properties of Nanocomposite Epoxy / Al_2O_3

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Abstract: ***This study was carried out to investigate the effect of ceramic nano filler (aluminum oxide Al_2O_3) with weight fraction (2, 4, 6, 8 and 10 wt%) on some mechanical and thermal properties of epoxy resin. The composites are fabricated by hand lay-up method. Some tests are carried out like: hardness, impact strength, thermal conductivity and thermal stability. The results have been compared with neat epoxy. It is observed that mechanical and thermal properties of epoxy composite are modified compare to neat epoxy, where the hardness, impact strength, thermal conductivity and thermal stability increases with increase the reinforcement ratio of nano-Al_2O_3.***

Keywords: Composite Material, Epoxy Resin and Al_2O_3, Hardness, Impact Strength, Thermal Conductivity and TGA

1. Introduction

A composite material can be defined as a mixture consisting of two or more substances of different specifications insoluble in one another to obtain a material whose physical and chemical properties differ from the properties of the materials inside in the composition where the properties of the resulting material are better than their components [1-5]. The composite material consists of two phases: matrix phase and reinforcing phase, matrix phase may be a metal, ceramic or polymer and reinforcing phase may be a particles, fibers, flakes, fillers or laminates [6,7]. Recently, interest in polymer-based composites has increased because of the specifications of this group of chemical materials, particularly applications using high quality resistance. The most important materials used as base materials are polymer materials of all three types thermoplastic, thermoset and rubber [8]. The real challenge for most of the materials engineers is modification composite material or development of new composite materials where there is an increase demand for advanced materials with better properties to meet new requirements. One of the approaches to develop new class of polymer is modification of it matrix by addition of ceramic powders of different sizes such as aluminum oxide (Al_2O_3) to achieve the required mechanical properties [9]. Al_2O_3 nanoparticles is important ceramic compound due to mechanical and thermal properties. It is used in many industrial applications such as refractories, abrasives and electrical insulators [10]. The aim from this study is studying the effect of Al_2O_3 nanoparticles with different weight fraction on some mechanical properties (hardness and impact strength) and thermal properties (thermal conductivity and stability) of epoxy resin.

2. Experimental Part

2.1. Materials

2.1.1.Polymer

Epoxy resin and hardener, imported from Sikadur-52 company, USA. Epoxy and hardener were used in this study in ratio of (2:1) for curing.

2.1.2. Reinforced Material

Aluminium oxide nanopowder is supplied from Hongwu International Group Ltd, China with purity 99.8%, particles size 80 nm and alpha phase.

2.2 Synthesis

The samples are formed by hand lay-up molding of epoxy resin with percentage weight (2, 4, 6, 8 and 10 wt.%) of Al_2O_3. The samples molded according to (ASTM DI-2240) for hardness test, (ISO-197) for impact strength and a tablet shape has a width (40 ± 0.2 mm) and thickness (4.0 ± 0.1 mm) for thermal conductivity test. The weight of samples for thermogravimetric analysis (TGA) testing was 22mg.

3. Result and Discussion

3.1 Hardness Test

The hardness was estimated by (Durometer Hardness) type (Shore D) factory by (TIME GROUP INC./ ITALY) company. Figure (1) shows the values of hardness of epoxy without and with additive. It can be seen that the hardness increases with increasing weight fraction of nanoparticles because the matrix transfers some of the applied stresses to the particles and therefore increasing in material resistance against the plastic deformation, this is in good agreement with [11].

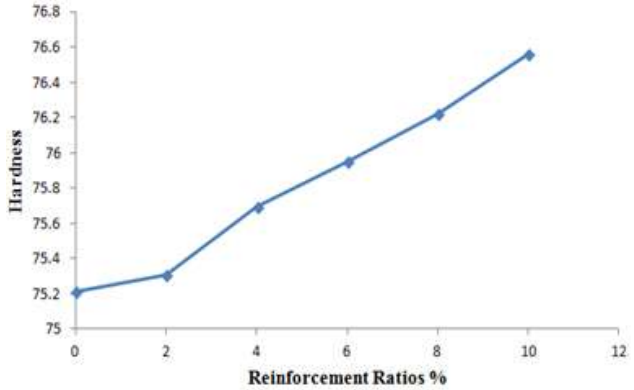

Figure 1: Relationship between hardness and the reinforcement ratio

3.2 Impact Strength Test

The impact strength was examined by a (US-made) instrument supplied by testing machines inc. (tmi) to determine the energy required to break or rupture samples by using international testing method for Charpy, this energy and impact strength of material were calculated as follows [12,13]:

$$E = E_1 - E_2 \quad \text{……… (1)}$$

$$I.S = E / bh \quad \text{……… (2)}$$

Where:

E : absorbed energy after impact (Joul).

E_1 and E_2 : are initial and final potential energies, respectively.

I.S : impact strength (KJ/m^2).

b : width of the sample (mm).

h : thickness of the sample (mm).

Figure (2) shows the values of absorbed energy in fracture of epoxy without and with additive. In general, the failure occurs in the unreinforced resin material subject to the impact test by breaking the bonds or forces in the polymer that one growing the initial cracks caused by impact stress. In fact, these cracks grow and propagate rapidly towards the interface surfaces separating between the polymer chains because the forces between these chains represented by Vander Waal forces which requires low energy to overcome it. The results show that the increase of the impact strength of the samples is by increasing the reinforcement ratios until (8 wt.%) because the nanoparticles work to withstand part of the impact stress exerted on the composite material and prevent the spread of the cracks in order to increase the bond between the base material and the reinforcing materials, this is in good agreement with [14].

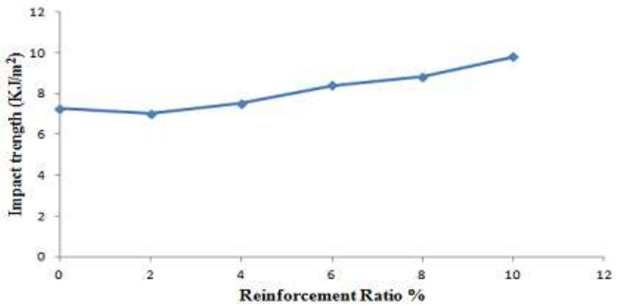

Figure 2: Relationship between impact strength and reinforcement ratio

3.3 Thermal Conductivity Test

The thermal conductivity was estimated by Lee's disk test which supplied by (Criffen and George company). The device consists of a heater (H) where the heat moves from it to the disk that follows it until it reaches the final disk where the heat is transferred through the model (S) and the subject between the disk (A) and (B). The temperature of the three discs is determined by using thermometers placed inside the discs [15].

A value of thermal conductivity coefficient of the specimens (K) of thickness (d) and radius (r) is calculated at different potentials across the heater (6 Volt), current which flows through it (0.25 Ampere) and time (1 hour) are measured by using following equation [16]:

$$K (T_B - T_A/d_S) = e [T_A + 2/r (d_A + d_S/4) T_A + d_S T_B/2r] \quad \text{….. (3)}$$

Where:

d_S, d_A, d_B and d_C : are the thickness of the sample and the disks respectively (mm).

T_A, T_B and T_C : are the temperature of the disks A, B and C (°C).

e : quantity of thermal energy be emitted from exposed area of the surface ($W/m^2.°C$) calculated by using following equation:

$$IV = \pi r^2 e (T_A + T_B) + 2\pi r e [d_A T_A + d_S/2(T_A + T_B) + d_B T_B + d_C T_C] \quad \text{….. (4)}$$

Where:

V: is the different potentials across the heater.

I : is the current which flows through it.

Figure (3) shows the obtained results of measurements of thermal conductivity (W/m.°C) for epoxy without and with different reinforcement ratios and found the reinforced with nanopowders leads to increase the thermal conductivity, because it works to reduce the degree of cross linking between the molecular chains that give them larger freedom of movement and increase the ability to vibratory movement, which leads to increase the thermal conductivity, this is in good agreement with [17].

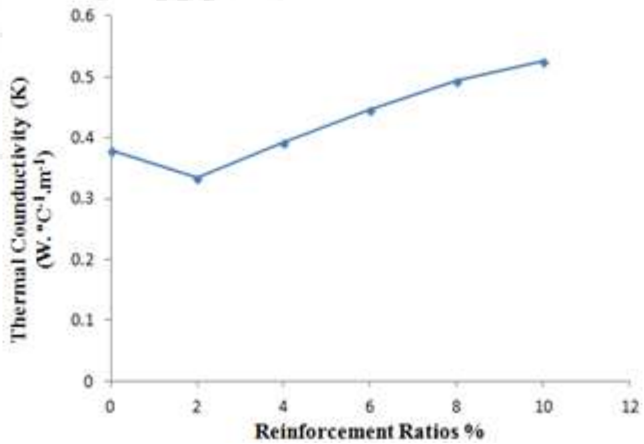

Figure 3: Relationship between K and the reinforcement ratio

3.4 TGA Test

The thermal degradation was studied using thermogravimetric analysis which carried out by (differential scanning calorimetry), model STA PT-1000 linseis. TGA is used to know the thermal stability of epoxy resin and the effect of additive on thermal stability for it. Figure 4, illustrates the TGA results of epoxy without additive and with (10 wt.%) additive. In two samples a change in peak was observed due to different melting behaviors of composite materials. There is no change in the starting of melting thermogram and there was a marginal increase in the ending of it, this difference is due to the nanoparticle penetrates inside the base material and works to fill and reduce the gaps that are formed during the molding process, which gave better thermal properties. The weight loss is due to the epoxy resin loses humidity by evaporation process then the epoxy begins to decompose.

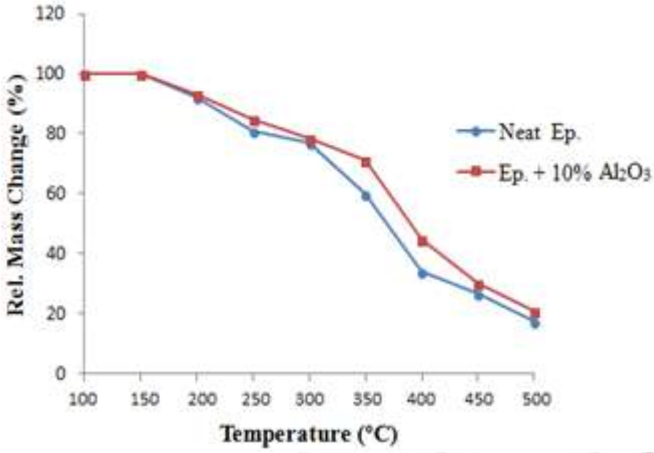

Figure 4: TGA curves of neat epoxy and epoxy/ 10% Al_2O_3 nanocomposite

4. Conclusions

Neat epoxy has lower mechanical and thermal properties than (reinforced epoxy) composites. Hardness is increased with the increase of weight fracture of epoxy resin for all reinforcement ratios. Increased reinforcement ratios helps increasing impact strength and therefore increases the absorbed energy required to fracture the sample. The thermal properties increase with increasing reinforcement ratios.

References

[1] D. Verma, P. Gope, M. Maheshwari and R. Sharma, "Bagasse fiber composites-a review", J. Mater. Environ. Sci., Vol. 3, (2012) .
[2] F. Campbell, "Structural composite materials", ASM International, (2010).
[3] D. Hull, "An introduction to composite materials", Camdridge University Press ,U.K, 1978.
[4] R. Jones, "Mechanics of composite materials", Script a Book Company, New York, (1975).
[5] S. Hassan, J. Jabir and R. Salman, "A study of the effect of acid immersion on some physical properties of (epoxy – MgO) composites", Iraqi Journal of Physics, Vol. 13, (2015).
[6] K. Kainer, "Basics of metal matrix composites ", Wiley-Vch Verlag, GmbH & Co. KGaA, Wrinheim, U.S.A., (2006).
[7] S. Thomas, J. Kuruvilla, S. Malhotra, K. Goda, and M. Sreekala, "Polymer composites: volume 1", 1st Ed., Wiley-VCH Verlag GmbH & Co. KGaA., (2012).
[8] Sh. Karim, S. Jassim and H. Naji, "Studying of thermal conductivity and impact strength for unsaturated polyester material reinforced by aluminum particles", The Iraqi Journal For Mechanical And Material Engineering, Special Issue (A).
[9] A. Abdul-Hussein, F. Hashim and T. Kadhim, "Effect of nano powder on mechanical and physical properties of glass fiber reinforced epoxy composite", Al-Khwarizmi Engineering Journal,Vol. 12, (2016).
[10] S. Leabi, "The effect of Al_2O_3 additives on some mechanical properties of unsaturated polyester resin", Ibn Al-Haitham Jour. for Pure & Appl. Sci., Vol. 27, (2014).
[11] B. Musa, "Effect of glass powder on some mechanical properties of polymer matrix composite material", Journal of Al-Nahrain University, Vol. 17, (2014).
[12] A. Erklig, N. Dogan and M. Bulut, "Charpy impact response of glass fiber reinforced composite with nano graphene enhanced epoxy", Periodicals of Engineering and Natural Scinces, Vol.5, (2017).
[13] B. Dheya and M. Ameen, "Effect of water absorption on impact strength of synthetic fibers with epoxy-unsaturated polyester blends", Iraqi Journal of Science, Vol. 57, (2016).
[14] S. Maki, O. Ahmed , M. Abdullah and B. Gheni, "A study of reinforcing and temperature effect of impact strength for polymer blend", Ibn Al-Haitham Journal for Pure and Applied Science, Vol. 25, (2012).
[15] B. Dheya and H. Mahmood, "Effect of NaOH on some physical properties of Novalac /TiO_2 composite", Iraqi Journal of Physics, Vol. 13, (2015).
[16] S. Alrubaiy, "Preparation and study of some physical and mechanical properties of hybrid epoxy particulate composites", Ph. D. dissertation, Baghdad, (2008).
[17] B. Deyaa, T. Hameed, "A study of the effect of nano materials on the physical properties of epoxy composites", Iraqi Journal of Physics, Vol. 15, (2017).