Effect of Al_2O_3 Powder on Some Mechanical and Physical Properties for Unsaturated Polyester Resin Hybrid Composites Materials Reinforced by Carbon and Glass Fibers

Reem Alaa Mohammed
Registration and Student Affairs Department, University of Technology/Baghdad.
Email: ra_aljubory@yahoo.com

Received on:12/5/2016 & Accepted on: 18/8/2016

ABSTRACT

This research is a study of the effect of Al_2O_3 powder on physical and mechanical properties of the polymer hybrid composites based on unsaturated polyester resin reinforced with carbon and glass fibers. The samples were made by a hand lay-up method according to ASTM standard for various volume fractions of additives. The polymer composites materials reinforced with carbon and glass fibers are the most used in manufacture of components such as pip, part of aerospace, and leisure industries and automotive. The polyester resin matrix was strengthened with 3% carbon and glass fibers with 1%, 3%, 5%, 7% Al_2O_3 powders. The water absorption, hardness (shore D), impact test, and flexural strength properties are studied. The results show the specimens (UP+3% C.F+7% Al_2O_3) and (UP+3% G.F+7% Al_2O_3) had the maximum hardness (shore D) and water absorption when compared with unfilled polyester resin specimen , it can be observed that the specimens (UP+3% C.F+5%Al_2O_3) and (UP+3% G.F+5%Al_2O_3) have maximum impact strength and flexural strength compared with specimens (UP+3%C.F+7%Al_2O_3) and (UP+3%G.F+7%Al_2O_3) .

Keyword: Unsaturated Polyester Resin, Carbon Fiber, Glass Fiber, Al_2O_3 Powder, Particle Size Analyzer, XRD, Water Absorption, Hardness (Shore D), Impact Test, Flexural Strength

INTRODUCTION

Hybrid composites are to combine advantageous features of kind's reinforcement systems – improved performance as well as reduced cost and weight. Hybrid composites facilitate the design of material with specific property matched to an end use. It is critical to understand the mechanical properties of hybrid composites to optimize the design of new hybrid materials [1]. Generally Hybrid applies to advanced composites and refers to use of type combinations of fibers or filler in either thermoplastic or thermoset matrices [2]. Fiber reinforced materials become important for constructions of all types of applications such as Airplane engine covers, Fire resistant decorative boards, body fillers, work-surfaces, helicopter rotor blades and pump impeller blades [3].

Polyester resin is one of the most commonly used polymer matrix with reinforcing fibers for advanced composites application due to its low cost, easy handling , corrosion resistant, flexible rigid, weather resistant and flame retardant [4].

Falak O. Abas et. al. (2010) have studied the effect of silicon carbide (SiC) and alumina (Al_2O_3) particles at various additional ratios as (0.2, 0.4, 0.6, 0.8, 1.0) volume fraction on thermal and mechanical properties of carbon, glass, and kevlar fiber / polyester resin composites. From the result can be shown that silicon carbide, have better filler characteristics compared to those of alumina [5].

Ibtihal-Al-Namie. et. al. (2011) have investigated the properties of composites material epoxy resin reinforced with ceramic powder. The reinforcement powder materials are silica and alumina with size particle (53-63) µm, (106 -150) µm respectively, with weight fraction of (20%, 30%, 40%) ranking. The result depicted flexural strength and hardness of composite materials are high than the matrix resin, also the flexural strength and hardness of composites reinforced with Al_2O_3 are significantly higher than composites reinforced with (equitant silica) content [6].

Ramesh K. N. et. al. (2014) have investigate of effect SiO_2, Al_2O_3, and TiO_2 particles micro in to improve properties mechanical of composite based on epoxy resin filled glass fiber with micro powder. The composites are made by hand lay-up technique. The result observed that flexural modulus and flexural strength are more in case of SiO_2 particles with epoxy resin composite compare to other particles. This is because silica has smaller particle size of comparing to others particles. Alumina particles with epoxy resin composite increases the impact energy and hardness compare to other SiO_2 and TiO_2 [7].

Objectives of the Research

The objective of this research is to:

1. Prepare composites of polyester resin reinforced with carbon, glass fibers with AL_2O_3 powder.
2. Study some physical and mechanical properties (water absorption, XRD, practical size analyzer, hardness shore D, impact test and flexural strength).

Experimental Work

Materials Used

The essential materials used in the preparation of the specimens consisting of carbon fibers of the type (Carbon UD Stockinette from Tenax Company) and woven roving fabric E-glass fiber from the Tenax Company, England , Table 1 shows typical properties of fibers carbon and glass . Unsaturated Polyester resin is used as the matrix. It is prepared from the Saudi Company and it was density of (1.255 gm / cm^3). Table 2 shows the typical properties of unsaturated polyester.

Table (1): Typical properties of fibers carbon and glass

Carbon Fiber	**Density (gm/cm^3)**	**Tensile Strength (MPa)**	**Tensile Modulus [GPa]**
	1.81	5600	290
Glass Fiber	**Density (gm/cm^3)**	**Tensile Strength (MPa)**	**Tensile Modulus [GPa]**
	2.58	3445	72.5

Table (2): Typical Properties of Unsaturated Polyester

Unsaturated Polyester	**Density(gm/cm^3)**	**Tensile Strength (MPa)**	**Percent Elongation (EL%)**	**Thermal Conductivity w/m.c^o**
	1.1	70.3 -103	<2.6	0.17

Preparation of Composites

The composites samples were prepared from polyester resin reinforced with glass , carbon fibers and Al_2O_3 powder in the volume fraction 1%, 3%, 5%, 7% as shown in table (3). The technique used in the preparation of the samples in this work is the Hand lay-Up Molding. Specimens are then extracted from the mould , and then heat treated in an oven at (60^0C) for a period of (60) minutes [8]. This process is very important for the purpose of obtaining the best cross linking between chains polymeric, and remove the stresses generated from the preparation process and complete the full hardening of the samples.

Table (3): designation and composition of hybrid composites

Designation of composites	Composition
A0	Pure polyester
A1	Polyester+3% C.F
A2	Polyester+3% C.F+1% Al_2O_3
A3	Polyester+3% C.F+3% Al_2O_3
A4	Polyester+3% C.F+5% Al_2O_3
A5	Polyester+3% C.F+7% Al_2O_3
B1	Polyester+3% G.F
B2	Polyester+3% G.F+1% Al_2O_3
B3	Polyester+3% G.F+3% Al_2O_3
B4	Polyester+3% G.F+5% Al_2O_3
B5	Polyester+3% G.F+7% Al_2O_3

Physical Tests

Water Absorption

The specimens for water absorption were prepared according to the ASTM D 570 at room temperature [9]. Specimens have been cut into a diameter of 50.8 mm and a thickness of 3.2 mm. Figure (1) shows standard specimens for this test. Water absorption ratio is determined by (Archimedes base) according to the following formula [9,10].

$$M (\%) = \frac{(mt - m_{\circ})}{m_{\circ}} \times 100 \qquad \text{………..} (1)$$

Where

M (%): water absorption percentage.

m_o : mass of specimen before immersion (g).

m_t: mass of specimen after immersion for seven days (g).

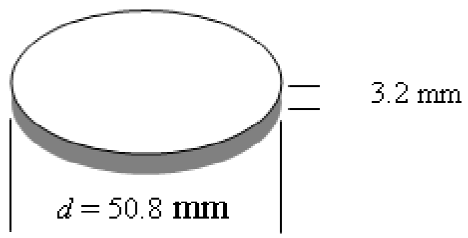


Figure (1): Standard Specimens [9]

Mechanical Test

Hardness Test (Shore D)

Hardness (Shore D) is conducted according to (ASTM D-2240) standard at room temperature. Specimens have been cut off into a diameter of 40mm and a thickness of 5mm [11]. Figure (2) shows standard specimens for this test.

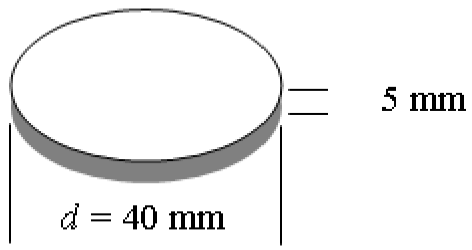


Figure (2): Hardness shore (D) standard specimens [11]

Impact Test

The impact tests of specimens were prepared according to (ISO-180 standard) [12]. Impact resistance is calculated for samples from the following relationship [13]. Samples have been cut into the dimensions (80*10*5) mm as shown in figure (3) [12].

$$Gc = \frac{Uc}{A} \quad \text{……. (2)}$$

Where

G_c= Impact strength of material (KJ/m^2).

U_c=Impact energy (J).

A= cross- sectional area of specimen (m^2)

Fracture toughness can be expressed as.

$$Kc = \sqrt{Gc\ E} \quad \text{…….. (3)}$$

Where:

K_c= Fracture toughness of material ($MPa.m^{1/2}$).

E= elastic modulus of material (MPa).

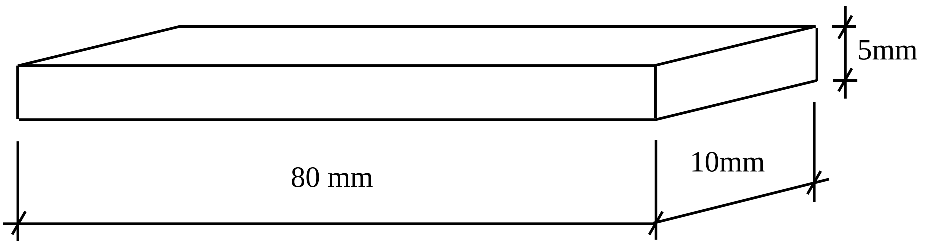


Figure (3): Impact test standard specimens [12]

Flexural Strength

This flexural strength is conducted according to (ASTM D790) at room temperature by three- point bending test machine (Lybold Harris No.36110).Samples have been cut into the dimensions (100*13*4.8) mm as shown in figure (4) [14].The flexural strength are calculated according to the equations [15].

$$F.S = \frac{3\,P\,L}{2bd^2} \quad \text{... ..… (4)}$$

Where

F.S: flexural strength (MPa).

P: force at fracture (N).

L: length of the sample between Predicate (mm).

b:thikness(mm).

d:width(mm).

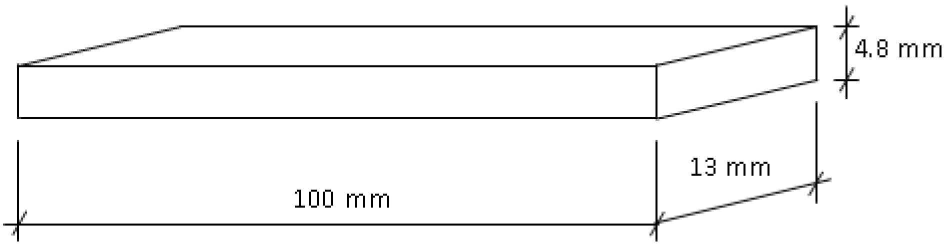


Figure (4): Flexural Strength test standard specimens [14]

Results and Discussion

XRD of Powder (Al_2O_3)

Figure (5) shows the x- ray diffraction of Al_2O_3high intensities of sharp peaks could be obtained, indicating a high crystalline in the synthesized powder. All peaks could be indexed to a monoclinic structure [16].

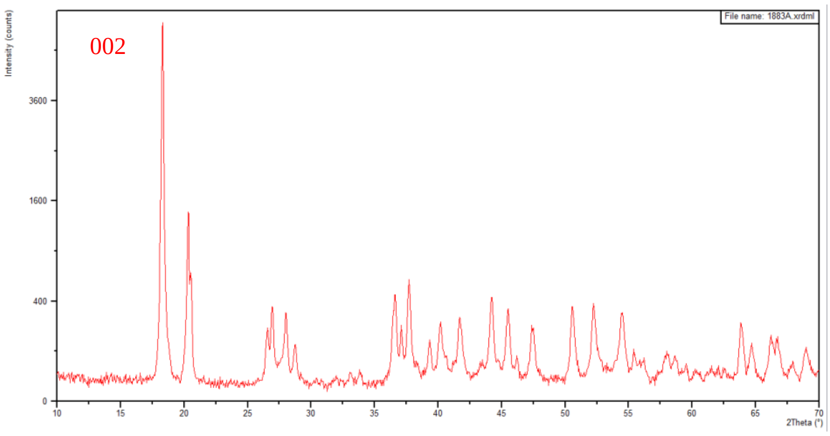


Figure (5): X- ray diffraction of micro-aluminum oxide powder

Particle Size Analyzer of Al_2O_3 Powder

The chart below shows the particle size distribution of Al_2O_3 powder, the size is found in the range (0.08-9.5) µm, and the mean particle size is equal to (1.914) µm. Also, it can be noticed that in the large size region of distribution, the number of particles is less than the number of particles in small size region, as shown in figure (6).

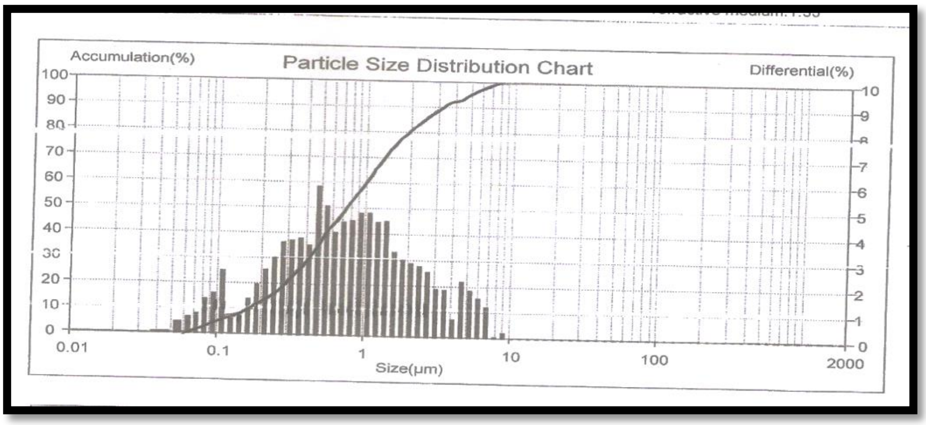


Figure (6): Particle size analysis of Al_2O_3 powder

Water absorption

The results of water absorption for the pure polyester and hybrid composites are illustrated in Figure (7). They results show the hybrid composites have the higher water absorption than pure polyester and the water absorption percentage depends on the rule of mixture, its increasing with increasing volume fraction of fibers and Al_2O_3powder. Fiber and Al_2O_3powder have higher percentage water absorption than the pure polyester. Also can be seen the specimens reinforced with (polyester + 3% carbon fiber +1, 3, 5, 7%Al_2O_3) have lower water absorption percentage than specimens (polyester + 3% glass fiber+ 1, 3, 5,7Al_2O_3). The water absorption attack the matrix – fiber interface, it causes de-bonding of the matrix and the fiber. The failures of the composite materials were due to voids and the porosity [17].

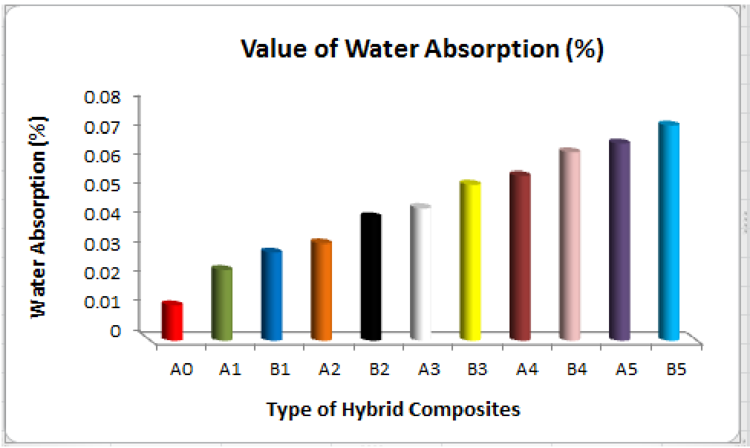


Figure (7): Effect of Al_2O_3 powder in value of water absorption of hybrid composites

Shore (D) Hardness

Figure (8) show the results of hardness shore (D) for the pure polyester and hybrid composites. From results the hybrid composites have the higher hardness and it increases with increasing volume fraction of the fiber and Al_2O_3 powder. Also can be seen the specimens reinforced with (UP+ carbon fiber +7% Al_2O_3) have higher hardness than specimens (UP + glass fiber+ 7% Al_2O_3). Increase in fiber and Al_2O_3 powder content leads to an increase in the hardness this may be due to the fact that the hardness is general considered to be a property of the surface , also Al_2O_3 powder contains an elements harder than the UPE that lead to an increase in hardness . The cause of increasing the hardness value in the Hybrid composite materials is the addition of filler particles lead to increased resistance material for plastic deformation [18].

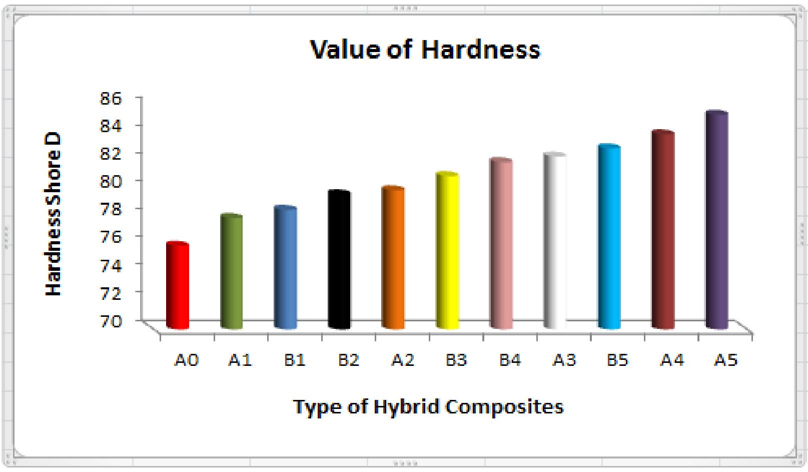
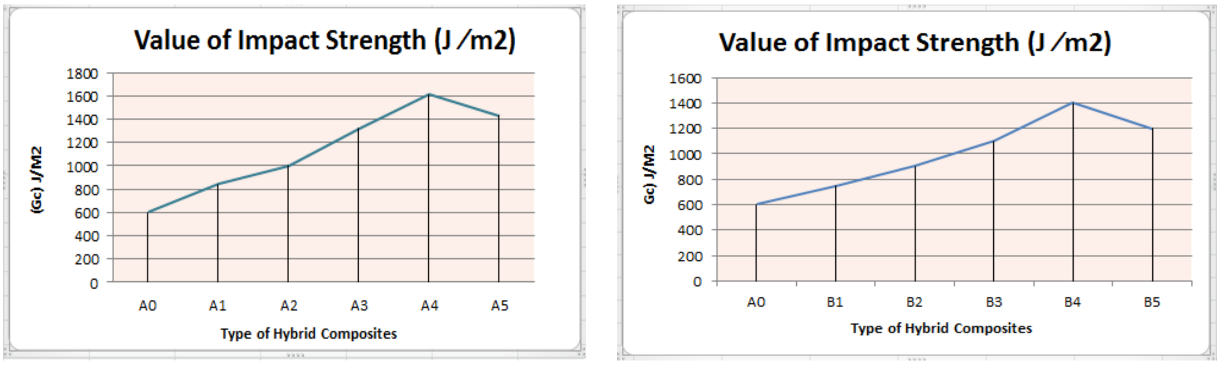


Figure (8): Effect of Al_2O_3 powder in value of hardness shore (D) of hybrid composites

Impact Test

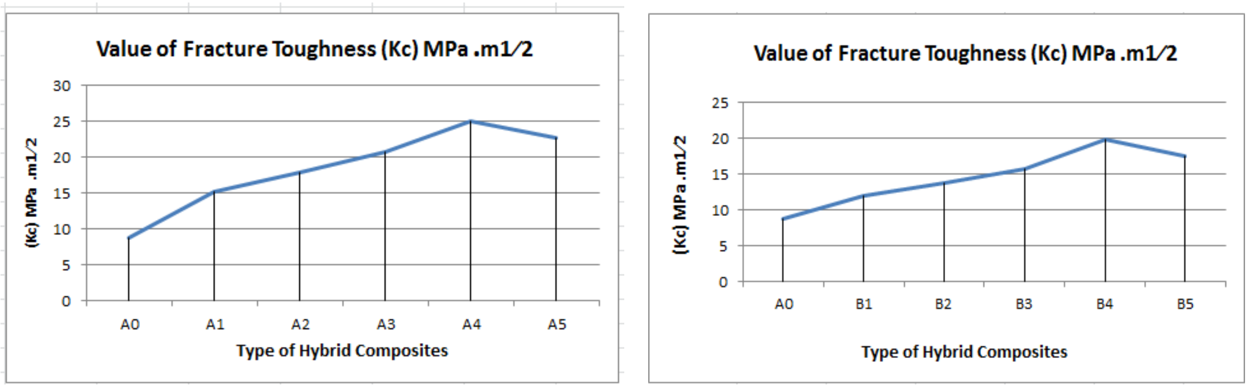
Figures (9, 10) show the values of fracture toughness (Kc) and impact strength (Gc) for polyester and hybrid composites. The results of (Gc) & (Kc) for pure polyester are lower than that of hybrid composites. The reinforcement's effect positively in bearing impact load and increasing the impact energy required to fracture the specimen. It is important to note that (C.F and GF with Al_2O_3 powder) have high shock resistance and durability. From the result can be seen the specimens reinforced with (UP +3% C.F+5% Al_2O_3) and (UP +3% G.F+5% Al_2O_3) have impact strength and fracture toughness than specimen reinforced with (UP +3% C.F+7% Al_2O_3) and (UP +3% G.F+7% Al_2O_3). Powder fillers (especially ceramics) may act as position for a localized stress concentration which the failure will begin, also it may help in the decreases of elasticity of material and reducing the deformability and ductility of the matrix, for the reason the composite tends to form a weak structure and the bad distribution of fillers reduces the capability of matrix to absorb energy and therefore decreases the toughness, even energy impact decreases [19], so that lower results of specimens reinforced with (UP +3% C.F+7% Al_2O_3) and (UP +3% G.F+7% Al_2O_3) .



A- UP+3% C.F+1%,3%, 5% ,7% Al_2O_3

B- UP+3% G.F+1%,3%, 5% ,7% Al_2O_3

Figure (9) (A, B): Effect of Al_2O_3 powder in value of Impact strength of hybrid composites



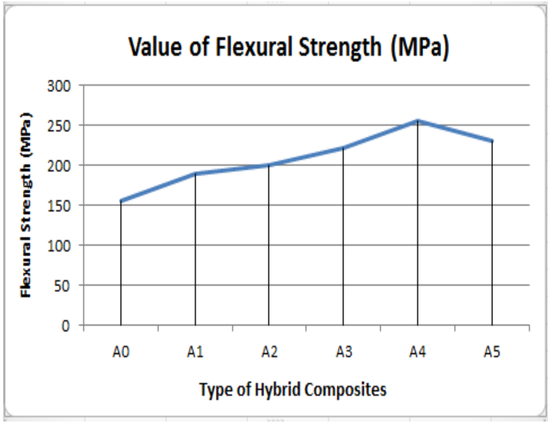
A- UP+3% C.F+1%,3%, 5% ,7% Al_2O_3

B- UP+3% G.F+1%,3%, 5% ,7% Al_2O_3

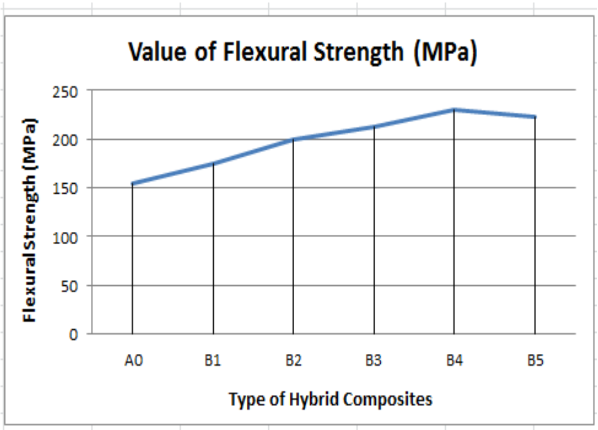
Figure (10) (A, B): Effect of Al_2O_3 powder in value of fracture toughness of hybrid composites

Flexural Strength

The results of flexural strength and powder of alumina appears in figure (11). This figure shown flexural strength increase with the increment of (1%, 3%, 5%) alumina, but decreased with addition (7%) alumina. Deterioration in structural integrity due to the presence of agglomeration and the voids of alumina in the matrix was found to be a primary cause of the decreases in flexural strength [19].



A- UP+3% C.F+1%,3%, 5% ,7% Al_2O_3



B- UP+3% G.F+1%,3%, 5% ,7% Al_2O_3

Figure (11) (A, B): Effect of Al_2O_3 powder in value of Flexural Strength

CONCLUSIONS

The main conclusions of results are:-

1. The hybrid composite specimens reinforced with carbon, glass fiber and Al_2O_3 powder have higher value of hardness shore (D), impact strength, fracture toughness and flexural strength than specimens of pure polyester, polyester+3%C.F and polyester+3% G.F.
2. The hybrid composite specimens reinforced with carbon, glass fiber and Al_2O_3 powder have higher value of water absorption than specimens of pure polyester, polyester+3%C.F and polyester+3% G.F.
3. Higher value of hardness was obtained at (UP+7% Al_2O_3) for two types of fibers.
4. The value of percentage impact strength, fracture toughness and flexural Strength decreases with increasing volume fraction of Al_2O_3 powder. Higher value of impact strength, fracture toughness and flexural Strength were obtained at (UP+5% Al_2O_3) for two types of fibers.

REFERENCES

[1] Steven, R., Desai, A. "Hybrid composite phenolic foams", University of Southern California, PP. 1-3 ,(2007).

[2] Satish, K. G., Siddeswarappa, B.& Mohamed, K. K.," Characterization of in-plane mechanical properties of laminated hybrid composites", University B.D.T. College of Engineering, No.2 , Vol. 9, PP. 106-108,(2010) .

[3] Herrmanna, H. & Eik, M.," Some comments on the theory of short fiber reinforced materials", Proceedings of the Estonian Academy of Sciences, No.3,Vol.60, Vol.60, PP.179-181 , (2011).

[4] M.Somaiah Chowdary and M.S.R Niranjan Kumar " Effect of Nanoclay on the Mechanical properties of Polyester and S-Glass Fiber (Al) " International Journal of Advanced Science and Technology ,Vol.74, PP.35-42 , (2015), http://dx.doi.org/10.14257/ijast.2015.74.04.

[5] Dr. 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 / Polyester Composites", Eng and tech.journal. ,No.12, Vol.28.PP .2469 ,(2010) .

[6] Ibtihal A. Ahmed A. and Manal F." Study the Mechanical Properties of Epoxy Resin Reinforced With silica (quartz) and Alumina Particles", The Iraqi Journal For Mechanical and Material Engineering, No.3,Vol.11, PP.486-505, (2011).

[7] Ramesh K. Nayak , Alina Dasha and B. C. Ray,"Effect of Epoxy Modifiers (Al_2O_3, Sio_2, Tio_2) on Mechanical Performance of Epoxy/Glass Fiber Hybrid Composites", Procedia Materials Science Journal, Vol.6, PP.1359-1364, (2014), (doi:10.1016/j.mspro.2014.07.115).
[8] J. McColm " Ceramic Science for Materials Technologists ", Leonard Hill, NewYork, (1983).
[9] Annual Book of ASTM Standard ,"Standard Test Method for Water Absorption of Plastics D 570- 98", , Vol. 08.01 (2005).
[10] Asmaashawky kalil " The Effect of Particles as Additives on Water Absorption for Epoxy Resin ", International Journal of Application or Innovation in Engineering & Management , Issue 5, Vol.2, PP.131-136 , (2013).
[11] Annual Book of ASTM Standard "Standard Test Method for Plastics Properties- Durometer Hardness D 2240", Vol. 09.01, (1988).
[12] "StandardTest Method for Izod Impact (Unnotched) ASTM D4812, ISO180", (2014) .
[13] Donald R. Askeland, Pradeep P.Fulay and Wendelin J.Wrigth, ”The Science and Engineering of Materials”,6th edition, Cengage Learning Inc., (2011).
[14] Annual Book of ASTM Standard, "Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics D 790- 86", Vol. 10.01, (1986).
[15] Ali I. Al-Mosawi, Dr. Mustafa A. Rijab, Nawal Abdullah, Saleh Mahdi "Flexural strength of fiber reinforced composite ", International Journal of Enhanced Research in Science Technology and Engineering, Issue 1,Vol. 2, (2013) .
[16] Saalfeld, H., "Neues Jahrbuch fuer Mineralogie" ,Abhandlungen (Band-Nr) (1950-), 95, PP. 1 - 87, (1961).
[17] Chandramohan, D. and J. Bharanichandar " Narural Fibre Reinforced Polymer Composites for Automobile Accessories ", American Journal of Environmental Science , No.6 ,Vol. 9 , PP. 494-504, (2013) (doi:10.3844/ajessp.2013.494.504) .
[18] Saad M.Elia , " Studying the Effect of Adding Sea Nodules Powders on Flexural Strength and Hardness of Unsaturated Polyester Resin" , Eng.&Tech. Journal , No.13 ,Vol.29 , (2011) .
[19] Jawad Kadhim Oleiwi , Farhad Mohammad Othman , Israa Faisal qhaze , " A Study of Mechanical Properties of Poly Methacrylate Polymer Reinforced by Silica Particles (Sio2), Eng.&Tech. Journal , No.15 ,Vol.31, Part (A) , (2013) .
[20] J. Xu, J. P. Donohoe and C. U. Pittman Jr.: Compos. Part A No.35, PP 693-701, (2004) .