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Investigation on Mechanical and Physical Properties of Fly Ash Reinforced Epoxy Resin Composite

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Abstract: *Fly ash is an inorganic alumino silicate, a by product of thermal power plant, responsible for air pollution. If we use it as second phase or reinforcement material in composite it will produce a suitable composite material as well as the pollution will be reduced. In this experiment for obtaining composite we have mixed the fly ash with epoxy resin, a matrix material in different ratio such as 10%, 20%, 30% and 40%. Different mechanical testing such as tensile test, hardness test and impact test are conducted to get the mechanical properties of composite. Roughness (R_a and R_z) test is done to check the smoothness. TGA and DSC analysis of 40% fly ash epoxy composite is carried out to find the thermal stability of composite.*
Key Words: *Fly ash, Epoxy resin, Impact test, TGA-DTA*

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I. Introduction

Now a days in various industries such as automobile, aircraft, electrical engineering etc., there is heavy demand of composite material specially polymer matrix composite because of it's high strength to weight ratio. Composite is made by matrix and reinforcement material. The function of matrix material to keep the reinforcement material, receive the external load and transfer it to second phase material. Where the second phase or reinforcement material is used for strengthening purpose [1,2]. In polymer matrix composite the common matrix material is epoxy resin due to its various suitable properties such as adhesiveness, chemically and environmentally inertness. The additional property of epoxy resin is that, it does not produce reaction products during curing and has low cure shrinkage [3]. The second phase or reinforcement material may be fibre or particulate type. The common fibrous filler materials are glass, carbon and aramid, whereas particulate type is ceramic powder [4]. Mishra and Shimpi observed that filler size reduction gives good properties of composite because of uniform distribution of filler material and also increasing cross linking of matrix material [5]. Fly ash, a particulate reinforcement material, is a by product of thermal power plant. It is mixer of different ceramic oxides such as alumina, silica, magnesium oxide and ferric or ferrous oxide and can be used as reinforcement or second phase material in polymer matrix composite [6, 7]. Beside this fly ash is harmful for human body and it is responsible for lungs cancer. The researchers are trying to use this in different ways. It is used to make portlant pozzolona cement, ash bricks etc. [8]. It is found that the fly ash-epoxy composite can be used for sound insulation layer, cover of the floor, canal projects, swimming pool and also prevent dam leakage purpose [9]. Now a days the researchers are studying the effectiveness of fly ash as strengthen material in polymer matrix composite. Sengupta et al. observed that tensile strength decreases due to addition of fly ash in polyurea composite [10]. Deepthi et al. investigated that fly ash addition in high density polyethylene improves the mechanical as well thermal properties of composite [11]. Singla and Chawla have found the compressive strength of fly ash- epoxy resin composite increases with increasing the amount the fly ash due to strong fly ash-epoxy interfacial bond and hollowness of fly ash particle [12]. Raja et al. have investigated the effect of size of fly ash on polymer matrix composite. They have found that minimum sized fly ash based composite shows better impact energy and hardness value because of large amount interface of fly ash and polymeric matrix [13]. Sahai and Pawar have seen that the impact strength, tensile strength and elongation at break of fly ash filled polyphenylene oxide composite decreases with increasing fly concentration. They conclude that interfacial stress developed at the interface of fly ash and polyphenylene oxide during curing which leads micro crack that reduces tensile strength [14]. Kishore and S. M. Kulkarni have observed that size and constituents affect the properties of composite [15].

The aim of this experiment is to quantify the influence of weight percentage fly ash on different mechanical properties such as impact strength, hardness, tensile strength of fly ash based epoxy composite and to correlate the physical behavior with weight percentage of fly ash.

II. Experimental Investigation

Materials: EPOTECH epoxy resin YD 522 is used as matrix material due to adhesiveness, chemically and physically inertness. Hardener ARADUR 140 is mixed with epoxy resin with the ratio of 13:37 by weight and the fly ash used for reinforcement. The orientation of second phase material that is fly ash is random manner. The chemical composition of fly ash is shown in table 1 [16].

Table 1: Chemical composition of fly ash

Sl. No	Compound	Amount in fly ash(in percentage)
1	SiO_2	55.85
2	Al_2O_3	24.98
3	Fe_2O_3	8.1
4	MgO	1.14
5	P_2O_5	0.15
6	SO_3	1.16
7	K_2O	0.85
8	CaO	2.54
9	Na_2O	0.2
10	TiO_2	1.75
11	CO_2	1.56

Fly ash is used as filler material and it is introduced for epoxy resin with various concentrations such as 10%, 20%, 30% and 40% by weight.

Mould preparation

Two moulds of size 150 ×100 × 3 mm are used for casting of polymer matrix composite slabs.

Dough Preparation

At first 37 gm of epoxy resin and 10, 15, 20 and 25 gm of fly ash are mixed respectively to make a 20, 30, 40 and 50 % fly ash composite and is stirred the mixture around 20 minutes in a beaker by a rod taking into care that no air should be entrapped inside the solution. After that 13 gm of hardener is added into it and stirred again about 15 minutes. Finally the dough is poured into the mould.

Table 2: Different sample with variation of fly ash

Sample	%Epoxy	%Fly ash	%Hardener
S1	74	20	26
S2	74	30	26
S3	74	40	26
S4	74	50	26

Fabrication of Composite

After cleaning and drying the lower surface of mould is greased so that the slabs could come out easily. The mixer is transformed in to mould and allowed to room temperature approximately 24 hours. After curing the slabs are taken out.

Testing Details

1) Tensile test is done in universal testing machine (Model No: LLYD10K+, made in England) at room temperature at Calcutta University to find out ultimate tensile strength and percentage of elongation. The test are carried out for the specimen of 60×10×3 mm, are cut from composite slabs.

2) Non standardized Charpy impact test is performed at room temperature in impact testing machine (Model No: IT 30, Range 0-300 Joules, Manufactured by Fuel Instruments and Engineers Pvt. Ltd) at Dept. of Mechanical Engineering, JISCE to get toughness of composite. The specimen dimension is 60×10×3 mm.

3) Rockwell hardness test is done in Rockwell/Brinell Hardness Tester (Model No: RAB 250 manufactured by Saroj Engineering Udyog Pvt. Ltd.) in F-scale at Dept. of Mechanical Engineering, JISCE. The testing load is 60 Kg and 1/16″ ball indenter is used to carry out the test at room temperature.

4) Surface roughness test is done by Taylor Hobson Talysurf (Model No: Surftest SJ-210 made by Mitutoyo) at Department of Mechanical Engineering, JISCE. The test is conducted at room temperature to obtain centre line average value (R_a) and ten point average value (R_z) of different specimens.

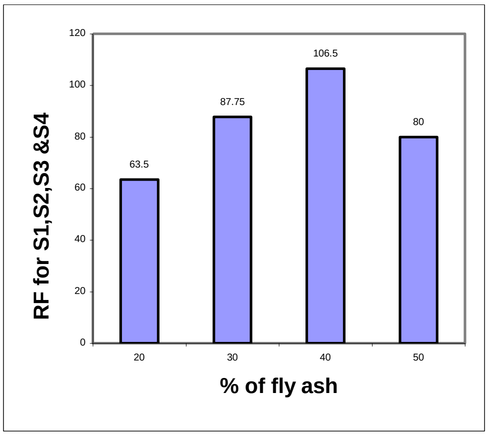
5) Thermo gravimetric Analysis (TGA) and Differential Thermal Analysis (DTA) test is conducted at room temperature in respective machine with Model No: Pyris Diamond TG-DTA, Make: PerkinElmer (Singapore) at Department of Metallurgical and Material Engineering, Jadavpur University. Platinum crucible is used with alpha alumina powder as reference. TGA and DSC analysis of 40% fly ash epoxy composite is carried out to find the thermal stability of composite.

III. Result and Discussion

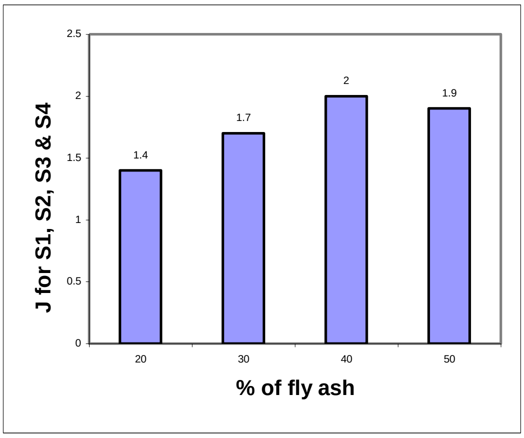
The ultimate tensile strength and percentage of elongation of composite with different percent fly ash are shown in table 3.It is observed that maximum tensile strength and also elongation is obtained for S2 sample where 30% fly ash is used but toughness and hardness is maximum for S3 sample is made by 40% fly ash. The variation of different mechanical properties such as hardness, toughness and tensile strength with percentage of fly ash is shown in figure 1. It is shown that beside toughness and harness the S3 (40% fly ash) sample has better surface roughness value.

Table 3: Values of different mechanical properties and surface condition of different sample

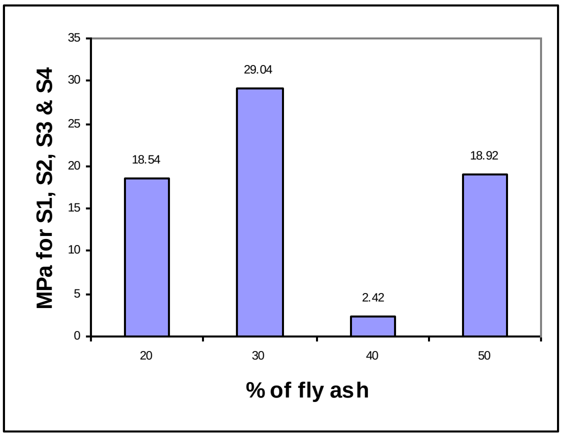
Sample	Tensile strength (MPa)	Elongation at fracture (mm)	Toughness (J)	Hardness (R_F)	Ra value (μm)	Rz value (μm)
S1	18.45	3.28	1.4	63.50	1.932	31.698
S2	29.04	3.65	1.7	87.75	1.849	32.971
S3	20.42	2.79	2.0	106.50	1.242	17.817
S4	18.92	3.08	1.9	80.00	2.256	21.73



(a)



(b)



(c)

Figure 1: Variation of a) hardness b) toughness and c) tensile strength with percentage of fly ash in fly ash-epoxy resin composite

TGA and DSC analysis of 40% fly ash epoxy composite is carried out in order to find out the thermal stability of the composite. The specimen is getting decomposed in three stages and in the first stage up to 100°C there is around 2% due to moisture loss, in the second stage and third stage there is around 5% and 3.2% mass loss respectively. The peak degradation is taking place at two temperatures initially at around 300 ºC and completed within 500°C the material lose is 55%. The Tg of pure epoxy was observed at 140.4 °C which is shifted to a higher temperature at around 190°C as shown in figure 2. The decrease in the free volume is proposed to be responsible for the increased Tg values. The exothermic degradation peak was observed at around 450°C from DSC study.

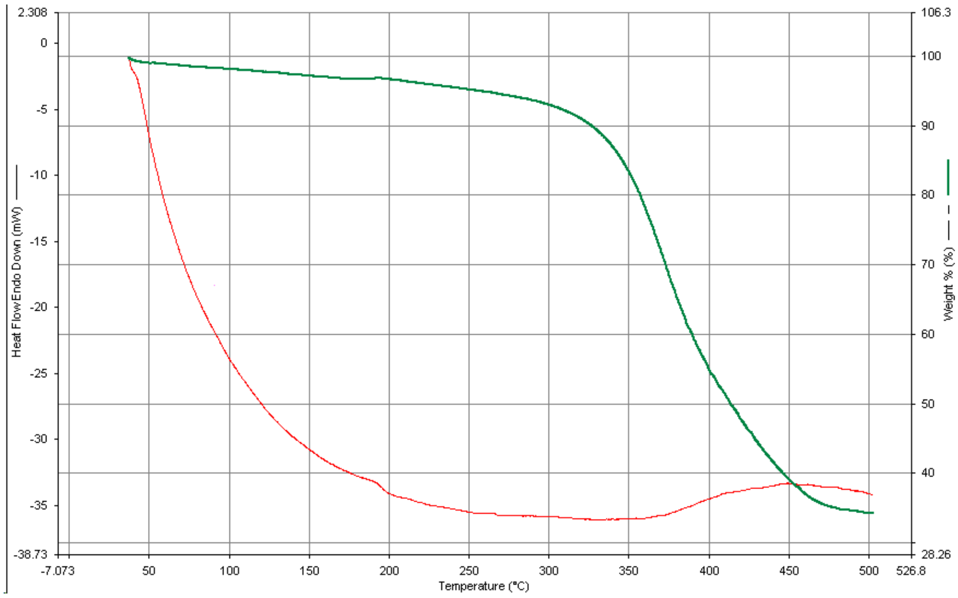


Figure 2: TGA and DSC analysis of 40% fly ash epoxy composite

IV. Conclusion

From the experimental observation it has been found that the toughness and hardness maximum for 40% fly ash contained composite that are 2 J and R_f106.50 respectively but tensile strength is better for 30% fly ash based composite. The surface roughness is better for 40% fly ash contained composite than others. It is shown that within 500^{0}C the material loses is 55% for 40% fly ash based composite.

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