Effect of Fly Ash Content and Particle Size on Mechanical Properties of Polyester-Based Composites

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Abstract— In present work, a class of polymer composite material is developed polyester as a matrix material with a micro-size fly ash as a filler material is developed. A set of composite specimens with filler content ranging upto 30 wt. % has been fabricated using simple hand lay-up technique for two different particle size i.e. 75 microns and 150 microns. The effect of filler content and particle size on different mechanical properties of the prepared sample is studied. The various mechanical properties evaluated are tensile strength, flexural strength, compressive strength and hardness From the experimental results, it is found that inclusion of fly ash enhances the mechanical properties of the material and composites prepared with smaller size particles delivers better result as compared to their counterpart.

Keywords—Epoxy, fly ash, tensile strength, flexural strength, compressive strength, hardness.

I. INTRODUCTION

In a captive thermal power plant, large amount of fly ash is produced when the burning of coal took place. The coal combustion process generates particles which are carried forward in flue gases and precipitated as solid spherical particles [1-2]. The utilization of generated fly ash is of huge concern as its disposal requires large area and pollutes nereby land, water and air. In past, fly ash is very limited utilized mainly for civil purpose that is for landfill, production of bricks and cement. Later, the scope of using fly ash widen up with increase in use to road embankment, bricks for lightweight construction and in cement industries. It is also been used as filler for development of polymer composites at low-cost. Fly ash filled polymer composites can be used in applications like in automobile, aerospace, transport and construction for load bearing application [2-5].

In past few years, lot of work has been carried out by the scientific community on fly ash reinforced polymer composites. Bachtrong et al. [6] reported the effect of fly ash content on dielectric properties of the epoxy/fly ash composites. They also modified the surface of fly ash 2 % steric acid and 2 % silane noticed the variation in dielectric properties of the material. From the analysis, they found that samples with fly ash modified by SA 2 % and silane GF80 2 % has significantly improved insulating properties compared to the non-modified fly ash samples. Ping et al. [7] investigated mechanical properties of epoxy/fly ash composites. They evaluated the flexural and impact behaviour of the material as a function of filler content. From the experimentation, they found that with increasing weight fraction of fly ash, the impact and flexural strengths and the flexural modulus of EP composite samples increased, and reached the highest values when the weight fraction of fly ash reached 15 wt%. Patra et al. [8] worked on evaluating the mechanical and thermal properties of the epoxy/fly ash composites and found ultimate tensile strength and percentage elongation is maximum for sample with 30 wt. % fly ash, whereas hardness is maximum for composites with 40 wt. % fly ash. They carried out the TGA and DSC analysis and and found improvement with added micro-particulates. Sim et al. [9] also evaluated the mechanical properties of epoxy/fly ash composites. They fabricated composites up to 50 vol % of fly ash for two different particle size of fly ash. They found that the tensile strength increased as the amount of fly ash increased, up to a critical point. On the other hand, they found that the compressive strength of the composite increased continuously as the amount of fly ash increased. Sroka et al. [10] investigated the effect silanization of fly ash on mechanical and thermal properties of the epoxy-based composites. They reported to achive enhancement in different mechanical and thermal properties of the material with the inclusion of fly ash in epoxy matrix. They found that salinization enhances the mechanical and thermal properties of the material even more. Against this background, an attempt has been made in this research work to develop micro-sized fly ash-based epoxy composites using simple hand lay-up technique and to study their mechanical properties like tensile strength, flexural strength, compressive strength and hardness.

II. MATERIALS AND METHODS

A. Material considered

Unsaturated isophthalic polyester supplied by Ciba-Geigy India Ltd. is taken as the matrix materials in the present investigation. Polyester is a category of polymer which contains the ester functional group in their main chain. The term unsaturated polyester resin is generally referred to the unsaturated (means containing chemical double bonds) resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Polyester resin is also known as a thermosetting plastic, which implies the plastic sets at high temperatures. Polyester resin composites are cost effective because they require minimal setup costs and the physical properties can be tailored to specific applications.

Fly ash is a by-product of coal combustion in thermal power plant. It consists of very fine particles of burned coal and comes out from boiler along with flue gases. In updated thermal power plant, this fly ash is separated from the flue

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gases with the help of filtering equipment or precipitator sothat only flue gases may come out from the chimney. The collected fly ash consists of particles of varying sizes. From those, particles of 75 microns size and 150 microns size are separated with the help of sieve. These are used for fabrication of two different sets of composites. Fly ash mainly consist of silicon dioxide, aluminium oxide and calcium oxide together with some other minerals. The exact composition depends upon the source and composition of coal. The fly ash is used in present investigation is of class F type. The filler used as fly ash obtained from Rourkela steel plant, Odisha, India. The fly ash was a spherical or non-uniform shape. The density of the fly ash is 2.2 g/cm^3.

B. Composite Fabrication

In the present investigation, micr-sized fly ash polyester composite is fabricated using simple hand lay-up technique. The fabrication of composite using hand lay-up method involves following steps:

1. The room temperature curing polyester and corresponding hardener methyl ethyl ketone peroxide (MEKP) are mixed in which hardener is added 2 % by weight as recommended.
2. Micro-sized fly ash will then added to the polyester-hardener combination and mixed thoroughly by hand stirring.
3. Before pouring the polyester/filler mixture in the mould, a silicon spray is done over the mould so that it will be easy to remove the composite after curing. The uniformly mixed dough is then slowly poured into the mould so as to get the specimens as per ASTM standard for the entire characterization test.
4. The cast is than cured for 8 hours before it was removed from the mould. In this process exothermic reaction between the matrix and hardener occur which hardened the composite body in this specified duration.
   Composites were fabricated with different weight fraction of filler ranging from 0 wt. filler i.e. neat polyester to 30 wt. % filler. Two categories of composites are fabricated with particle size 75 microns and 150 microns respectively. The composite fabricated under the investigation is given in table 1

TABLE I
POLYESTER COMPOSITES FILLED WITH FLY ASH

Composition			
Category I		**Category II**	
Set A1	Polyester + 5 wt. % Fly ash (75 microns)	Set B1	Polyester + 5 wt. % Fly ash (150 microns)
Set A2	Polyester + 10 wt. % Fly ash (75 microns)	Set B2	Polyester + 10 wt. % Fly ash (150 microns)
Set A3	Polyester + 15 wt. % Fly ash (75 microns)	Set B3	Polyester + 15 wt. % Fly ash (150 microns)
Set A4	Polyester + 20 wt. % Fly ash (75 microns)	Set B4	Polyester + 20 wt. % Fly ash (150 microns)
Set A5	Polyester + 25 wt. % Fly ash (75 microns)	Set B5	Polyester + 25 wt. % Fly ash (150 microns)
Set A6	Polyester + 30 wt. % Fly ash (75 microns)	Set B6	Polyester + 30 wt. % Fly ash (150 microns)

C. Mechanical Characterization

The tensile strength of the composites is measured with a computerized Tinius Olsen universal testing machine in accordance with ASTM D638 procedure by applying uni-axial load through both the ends at a cross head speed of 2 mm/min. The method by which the compression test is conducted is in accordance with ASTM D695 with same universal testing machine. The three-point bend test was carried out in Universal Testing Machine (UTM) in accordance with ASTM D2344-84 to measure the cross breaking strength of the composites. ASTM D2583-67 Barcol Hardness test method is used to determine the hardness of both reinforced and non-reinforced rigid plastics.

III. RESULTS AND DISCUSSION

A. Tensile strength

The tensile strength of all the fabricated samples of category I and II are measured by universal testing machine and are shown in figure 1. It is observed from the figure that the tensile strength of composite decreases with increase in filler content. The decreasing trend is seen for both categories of composites. The minimum tensile strength for category I composite reported is 34.1 MPa and 31.5 MPa for category II composites against the tensile strength of 40 MPa. The reduction in tensile strength at 30 wt. % fly is 14.75 % and 21.25 % respectively.

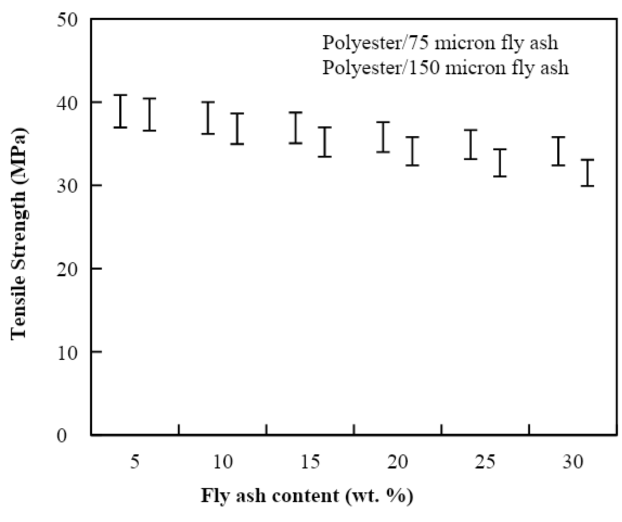

Fig. 1 Tensile strength of polyester filled with different particle size of fly ash

The reduction in tensile strength with increase in filler reinforcement may be due to the weak chemical bond between filler and the matrix body which is unable to transfer the tensile load.

B. Flexural Strength

The flexural strength of different sets of composites are presented in figure 2. From the figure it is clear that there is an increasing trend in flexural strength as the filler contents in the composite increases. Flexural strength of neat polyester is measure to be 45 MPa. The maximum value of flexural strength for composite under category I is 54.8 MPa for set A6 and under category II is 54.1 MPa for set B6. This is an increment of around 21.8 % and 20.2 % for category I and II respectively.

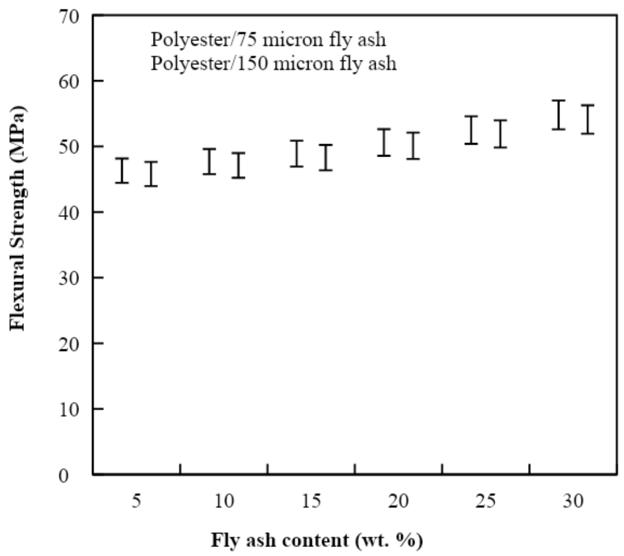

Fig. 2 Flexural strength of polyester filled with different particle size of fly ash

C. Compressive Strength

The dependence of compressive strength of polyester composites filled with fly ash with different filler content and size of particles shown in figure 3.

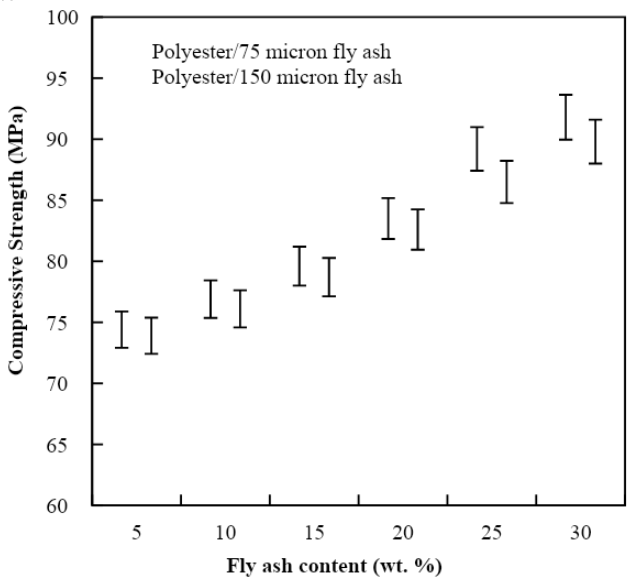

Fig. 3 Compressive strength of polyester filled with different particle size of fly ash

It can be seen from the figure that with increase in content of fly ash, compressive strength of the composites increases irrespective of the particle size of the fly ash and this increasing trend continuous till the maximum content of filler is added in polyester resin. The compressive strength of neat polyester is 72 MPa which increases to 91.8 MPa at a loading of 30 wt. % of micro size fly ash for category I composites. In this case 27.5 % enhancement in the value of compressive strength is reported for maximum content of filler. Similarly, for category II composites, compressive strength reaches to 89.8 MPa with an increment of 24.7 % over neat polyester.

D. Hardness

In the present investigation, the hardness values of the fabricated composites are measured using Barcol harness tester. The results obtained during the experimentation of category I and category II types composites are shown in figure 4.

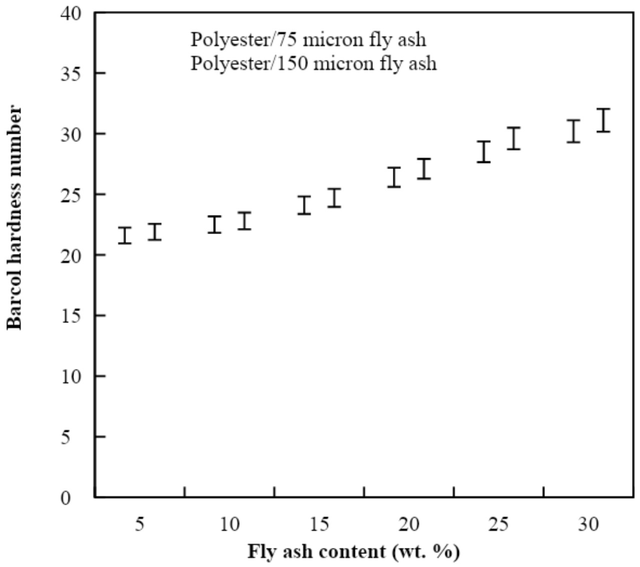

Fig. 3 Hardness of polyester filled with different particle size of fly ash

From the figures it is clear that, with the increase of filler loading, hardness of the fly ash-polyester composites increases. Barcol hardness number for neat polyester is 21.6. For category I composites, hardness is maximum for filler content of 30 wt. % i.e., set A6. The reported value is 30.2 Barcol hardness number. This is an increment of 41.7 %. It is further observed that when larger size of fly ash is used for fabrication of composites, maximum barcol hardness number attained is 31.1. This is an increment of 44 % for set B6. It is observed that, composite prepared with larger particle size possesses higher hardness as compared to its counterpart.

IV. CONCLUSIONS

This experimental investigation on fly ash filled polyester composites has led to the following specific conclusions:

1. Successful fabrication of polyester matrix composites reinforced with fly ash is possible by simple hand-lay-up technique.
2. The ultimate tensile strength of the fabricated composite decreases with increase in fly ash content. Further, composites prepared with smaller filler size has higher tensile strength as compared to composites prepared with larger filler size.
3. The flexural strength of the fabricated composite increases with increase in filler content. The maximum value of flexural strength for polyester composite is with 30 wt. % of the fly ash for both the categories of composites.
4. The compressive strength is gradually increasing with addition of micro-sized fly ash particles in polyester matrix. Rate of increase of compressive strength is

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appreciably depends upon the size of the particle used. When polyester is used smaller size particles, compressive strength is higher as compared to when polyester is used with larger size particles.

5. The hardness of the composites increases with the increase in the content of fly ash in polyester matrix. Barcol hardness number for neat polyester is 21.6. For category I composites, the reported value of hardness is 30.2 Barcol hardness number. Hardness increases further when larger size of fly ash is used and reaches maximum to 31.1 Barcol hardness number.

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