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Evaluation of Mechanical and Water absorption properties of Fly ash filled High Density Polyethylene Composite produced by Compression Molding

D. Santha Rao, Sanapala Manikanta, Pragada Durga Manikanta, Pikki Dhanu Venkat, Sambattula Raju

Department of Mechanical Engineering, Godavari Institute of Engineering and Technology(A), JNTUK, Kakinada.

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ABSTRACT

Composite materials emerged in the middle of the twentieth century as a promising class of engineering materials providing new prospects for modern technology. The wide range of property values attained with composites and the ability to tailor the properties is an advantage. Now a days composites are used in many areas like automobile, transportation and aerospace, etc. due to having unique properties like light weight, better strength, low maintenance, high strength to weight ratio. Polymer matrix composites with filler material as reinforcement have better properties than natural fiber reinforced composites. Utilization of inorganic filler materials obtained from waste has gained an importance due to burden on environment. One of such is utilization of fly ash particles which are interesting because of their low density, low cost, strong filling ability, and smooth spherical surface. In this present project work, A polymer matrix composite was fabricated by compression molding process with fly ash as filler material ranging from 5% to 25% by weight and high-density polyethylene (HDPE) as matrix material with constant applied load on the composite. The fabricated composite was tested for mechanical properties such as tensile strength, impact strength, flexural strength and hardness as per ASTM standards. Water absorption test was also carried out for water absorption rate. The results indicated that increasing the amount of fly ash content up to 25 % improves the hardness, tensile, flexural and impact strength of the composites. But the tensile strength was gradually decreases with the after 10% increment of fly ash in HDPE composite. It can be also observed that water absorption rate has increased with an increase of fly ash proportion.

KEYWORDS:High density polyethylene, Fly ash, Tensile strength, Hardness, Water absorption.

1. INTRODUCTION

Composite materials have attracted more interests in various potential applications in last decades such as aerospace, military, automotive and many other industries. These become most popular due to their excellent properties like Light weight, Ease of fabrication, High corrosion resistance, High wear resistance, High strength and stiffness, better strength to weight ratio, etc. [1]. Composite material is defined as the combination of two or more materials with different properties, without dissolving or blending them into each other. It consists of majorly two constituents; one is Matrix material and another one is Reinforcement material. The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material. Although, matrix materials are generally ceramics, metals, and polymers, the majority of matrix materials that exist on the composites market are polymer [2]. Polymer matrix composites being manufactured by hand layup, compression molding, injection molding in cost effective manner. Different types of polymers such as epoxy, polyvinyl, polyethylene, polystyrene, etc. are used with continuous/short fiber or filler materials such as carbon fiber, glass fiber, fly ash, saw dust, etc. in the production of polymer composites. In fact, most of the polymer matrix composites are filled with different inorganic fillers such as silicon carbide, aluminum oxide, silica, magnesium hydroxide, zinc oxide, etc. to attain the desired mechanical properties [3]. However synthetic composites are costly, non-biodegradable, and causes environmental pollution when they are discharged into environment.

Utilization of inorganic filler materials obtained from wastes has gained an importance due to effect on environment. One of such sources is utilization of waste fly ash particles which are exciting because of their properties like low density, low cost, strong filling ability, and smooth spherical surface [4]. Fly ash (FA) is a waste by-product generated aplenty by combustion of coal in thermal power stations. Fly ash consists primarily of oxides of silicon, aluminum iron and calcium. Magnesium, potassium, sodium, titanium and Sulphur are also present to a lesser degree [5]. Increasing production of fly ash year by year, from the coal based thermal power plant, is posing a serious problem in terms of its safe disposal and utilization. Thus, the utilization of fly ash as filler material in polymer composites is considered as important from both economic and commercial point of view [6].

On the other hand, High density polyethylene (HDPE) is one of the most common thermoplastic polymers that been used in many applications due to its excellent balance between properties like mechanical property, thermal property and chemical property [7]. The types of plastics commonly used in Polymer composites production and processing are Polyvinyl chloride (PVC), Polyethylene (PE), Polypropylene (PP) because of their low melting points and good thermos-plasticity. Among all, HDPE has added advantages of high shrinkage, easy forming, high melt strength and relatively mature processing technology, that is why HDPE composites are widely used in potential applications [8].

2. REALATED WORK

Fu Yee Xuen et. al. [7] studied the mechanical performance of high-density polyethylene composites filled with Quarry dust. They found that the addition of Quarry dust as filler material in the HDPE composites significantly affects the crystallization behavior of HDPE. The quarry dust has the potential to be used as filler in HDPE composites with improved properties. They concluded that flexural strength of composite increases slightly with increment of quarry dust content. S. Sivarao, Z. Jamaludin, M.S. Salleh, M.A.M. Ali, K. Kadirgama, U.K. Vatesh, S. Pujari, S. Sivakumar, S. Ramesh, K.Y. Sara lee et. al. [9] also observed that effects of sugarcane bagasse fibers on the mechanical behavior of high-density polyethylene. They found that the addition of 20 % and 30% bagasse content in HDPE composite has improved the flexural modulus and Rockwell hardness when compared to the fiber free HDPE. It was found that the incorporation of 10 to 40% bagasse fibers demonstrated a mix effect on the mechanical properties of the composites.

Vinay Kumar, Dr Amit Telang, Dr R.S. Rana et. al. [4] made an analysis of mechanical properties of HDPE, fly ash and Carbon nanotubes reinforced hybrid composite. They concluded that the concept of fly ash incorporation into High density polyethylene composites was found very useful way of utilization of fly ash waste. Also confirmed that impact strength increases with increment in fly ash content, Flexural strength first increases and then decreases, tensile strength decreases with increasing weight percentage of fly ash. Issac O. Igwe, Genevive C. Onuegbu et. al. [10] studied the properties of egg shell and fish bone powder filled polypropylene composite. They observed that various mechanical properties such as tensile strength, flexural strength, impact strength, hardness and specific gravity, etc. of polypropylene composite were improved with increment of filler content and decrease in filler particle size. Water absorption rate also increased with increase of filler content compared to unfilled polypropylene.

Jitendra Gummadi, G. Vijay Kumar, Gunti Rajesh et. al. [11] worked on evaluation of flexural properties of fly ash filled polypropylene composites. In this research work, they developed particulate composites from recycled polypropylene filled with fly ash. They mixed fly ash with polypropylene at different compositions from 0%, 10%, 15%, 20%, 25% by weight. Injection molding technique followed by hand layup method is used for making composites. They observed and concluded that flexural strength, flexural modulus and stiffness of polypropylene was improved with addition of fly ash gradually. But, the percentage elongation at break was dramatically reduced with increment of fly ash content. Mohammed N. Alghamdi [13] has studied that effect of filler particle size on the recyclability of fly ash filled HDPE composites. Melt Mixing and injection molding techniques are used for making composites in this work. The results of this study found that the use of small particles of fly ash could give rise to the tensile modulus and tensile strength of their reinforced composites when compared to pure HDPE material.

3. PROPOSED WORK

Review of literature survey shows that different type of properties like mechanical, thermal,dielectric, rheological, morphological were studied on the particulate composites made from fly ash, saw dust, etc. as a filler and thermoplastic materials like Polypropylene, Polyvinylchloride, High density polyethylene as a matrix medium. However, there is a limited literature available on the particulate composites especially made from Polypropylene and fly ash. Hence in the present study particulate composites made from high density polyethylene and fly ash are fabricated and studied for different mechanical properties, water absorption characteristics and the results are analyzed.

3.1. Materials:

a. Matrix material:High density polyethylene (HDPE) in pellets form was supplied by India Oil Corporation Limited (IOCL), Panipat, Haryana, India, shown in figure 3.1 (a).

(a)(b)

Figure 3.1:(a) HDPE(b) Fly Ash (FA)

b. Reinforcement material: Fly Ash (FA) as filler material was purchased from parshwamani metals (Vadgama Building, near C.P. Tank Road, Mumbai: 400004) which has 99% Purity and 150 mesh in size. The Chemical analysis of the fly ash is tabulated in Table 1. Fly ash power sample was shown in figure 3.1 (b).

Table 1: Chemical analysis report of Fly Ash used

Chemical Composition	**Concentration (%)**
Al_2O_3	22.87%
Fe_2O_3	4.67%
CaO	3.08%
TiO_2	0.94%
MgO	1.55%
K_2O	2.19%
Na_2O	0.62%
SiO_2	Remaining

3.2. Method for Fabrication of composite:

Polymer matrix composite materials can be produced by various methods such as injection molding, compression molding, Hand lay-up technique, spray lay-up, vacuum molding, etc. The compression molding process was used for preparation of composite. Compression molding is the process of applying pressure and heat for certain time in order to get the product.

3.2.1. Die Preparation:

A lower die with heating coils and upper die with attached bush were prepared as per assumed dimensions (150mm×100mm×15mm) of workpiece. Mild steel is used for making these dies. The different operations such as milling, surface grinding, jig boring was used in the fabrication of dies. Heating coils were mounted at the bottom of the die by making circular holes to the lower part of die. Upper part of the die is arranged to fit into hydraulic press for the application of load. The compression molding dies were appearing after fabrication and assembling process as shown in figure 3.2(a).

(a) (b)

(c)

Figure 3.2: (a) Compression Molding Dies (b) Component made by compression molding(c) Equipment Set up

3.2.2. Preparation of composites:

The Fly Ash filled HDPE composites were prepared by compression molding technique. The experimental set up for making composites by compression molding was shown in figure 3.2 (c). Initially, the mold die was refined with release agent to avoid HDPE stabbing to it. Then, HDPE pellets were placed in the mold and heat input was given to die through heating unit. Fly Ash was added after HDPE comes into molten state. Mixing was carried out at that temperature to get homogenous mixture of fly ash with HDPE. Now the Die with that mixture was placed under the hydraulic press and load was applied gently on the mixture for certain time so that it becomes a product. Hence heating unit is switched off and die was allowed to cool till it reaches room temperature. After that, die is taken out and sample is also taken out. The above procedure is repeated with different reinforcement percentages in HDPE. Resulting Samples from above production were machined into standard sizes for testing as per ASTM standards. The sample product produced by compression molding was shown in figure 3.2 (b). The formulation of FA – HDPE composites is tabulated in Table-2.

Table -2 Formulation of Fly ash – HDPE Composites

Sample	Fly ash (wt%)	HDPE (wt%)
H1	0	100
H2	5	95
H3	10	90
H4	15	85
H5	20	80
H6	25	75

3.3.Characterization of Composite Samples:

Different testing procedures were adopted to compare the influence of various compression molding parameters and fly ash content on the mechanical properties and water absorption property of the composite sample specimens by tensile testing, hardness testing, Water absorption tests.

3.3.1. Tensile Test:

Tensile Strength refers to the amount of load or stress that can be handled by a material before it stretches and breaks, cracks, or otherwise fails. The tensile properties of composite specimens were measured with a universal testing machine (200kN of maximum load capacity) according to ASTM D638-02a standards [12]. The dimensions of the test specimens were 165mm×19mm×5mm. A load was applied to each sample, at a cross speed of 5mm/min. Six samples were tested for tensile strength with different reinforcement content of composition. The specimens after and before tensile test were shown in figure 3.3 (a), 3.3(b) respectively.The tensile strength of the specimens was calculated by using the below formula,

$$\text{Tensile Strength}, \sigma = F/A$$

Where, F= Force in Newtons, A = Area of cross section in square meters.

(a)

(b)

Figure 3.3: (a) Tensile test sample specimen (b) Tested specimen after break

3.3.2. Hardness Test:

This test refers to measure the hardness of composite material, which is defined as the resistance of a material exhibits to permanent deformation by penetration of another harder material. The hardness of the composite samples was determined by a Rockwell hardness testing machine, according to ASTM D785 standard. A ball type indenter was used to perform the hardness test. A load of 60 kg was applied on the sample specimen and surface indentation was measured from the dial indicator.

3.3.3. Impact Test:

In this test, Specimen is tested for toughness and amount of energy absorption capacity of that material before failure. Impact Strength refers to the resistance of a material to fracture by a blow, expressed in terms of the amount of energy absorbed before fracture. Using the Charpy impact test rig, this test was carried out on the sample of composite material according to ASTM D256 standard. A load pendulum blew kinetic energy onto test specimen standing upright. During the test, a scale was used to measure how much energy was absorbed by the material before it broke apart. The specimens before and after impact test were shown in figure 3.4(a), 3.4(b) respectively.

(a)

(b)

Figure 3.4. (a) Impact test specimen (b) Tested Specimen of Impact test

3.3.4. Flexural Strength test:

Flexural test is performed to find out the strength of material before breaking during bending. On the universal testing machine, with a load capacity of 200kN, a flexural test was conducted according ASTM D790 standard. The dimensions of the test specimens were 120mm×13mm×5mm. The three-point bend fixtures were attached to the universal testing machine in order to perform Flexural strength test. The set up for flexural testing on UTM was shown in figure 3.5(c). The load was applied gently at the center of the specimen. The specimens after and before doing the test were shown in figure 3.5(a), 3.5(b) respectively.The flexural strength of the specimens was calculated by using the below formula,

$$\text{FlexuralStrength}, \sigma = \frac{3FL}{2wd^2}$$

Where F= force in Newtons, L= Length between supports in m, w=Width of the specimen in m, d= depth or thickness of the specimen in m.

(a)

(b)

(c)

Figure 3.5. (a) Flexural test specimen (b) Tested Specimen of Flexural test (c) Experimental set up of flexural test

3.3.5. Water Absorption Test:

Water absorption tests were carried out as per ASTM D570 test method. Each sample of composite with different weight percentages of fly ash content were dried before its weight was recorded as the initial weight of composites. The Samples were then placed in water and maintained at room temperature (270C) for 24 hours. After that the sample were removed from the water and weighed. The amount of water absorbed by the composites (in percentage) was estimated by using following equation

$$\%W = \frac{(W_f - W_i)}{Wi} \times 100$$

Where, Wf is the weight of the composite after water immersion and Wi is the weight dried sample before immersion.

4. RESULTS

4.1. Tensile Strength:

Results obtained from tensile strength test indicated that an increase fly ash loading has the tendency to increase the composite strength as shown in figure 4.1. HDPE composite with 10% fly ash as filler material has the highest tensile strength compared with pure HDPE. But further increment of fly ash content in HDPE composite reduces the tensile strength of the composite. The highest tensile strength of 34.2 MPa was obtained for 10% fly ash content in HDPE composite which was 50%

more than pure high-density polyethylene. Some studies were experimented on 10% of fly ash loading in the HDPE composite showed the highest tensile strength which is 22.5Mpa.

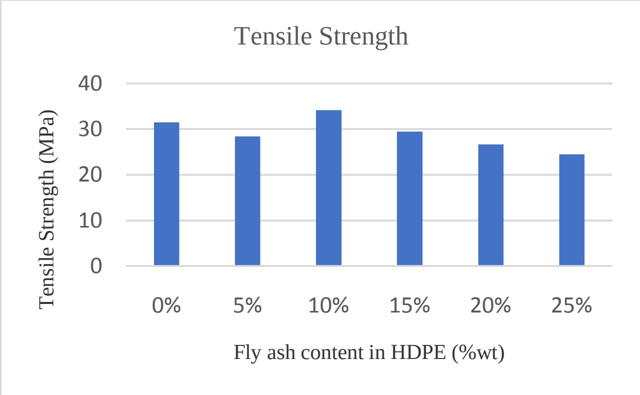

Figure 4.1. Effect of fly ash content on Tensile Strength

4.2 Hardness:

Result of the hardness test shows that, hardness of the composite samples was improved with increment of fly ash content in HDPE. The highest hardness of 42 was obtained for 25% fly ash content in HDPE composite which was more than pure high-density polyethylene. The effect of fly ash content on hardness of the composite was shown in figure 4.2.

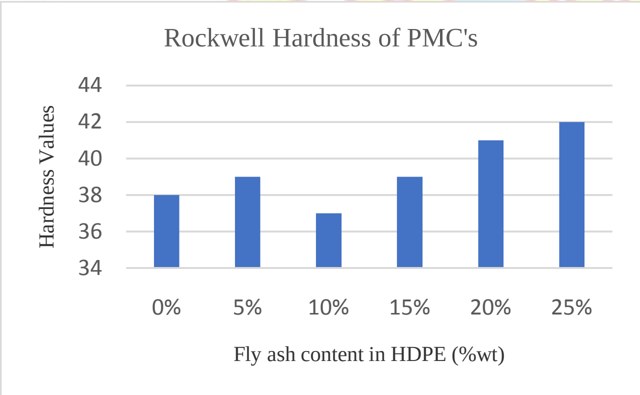

Figure 4.2. Effect of fly ash content on Hardness

4.3. Impact Strength:

Figure 4.3 shows the results of the impact tests, indicates that the impact strength of the composites increases as the fly ash loading increases. The highest impact strength of 5.2 J/cm2 was obtained for 25% fly ash content in HDPE composite which was 73% more than pure high-density polyethylene. It can be concluded that impact strength of HDPE composites was increased by the addition of fly ash as filler material.

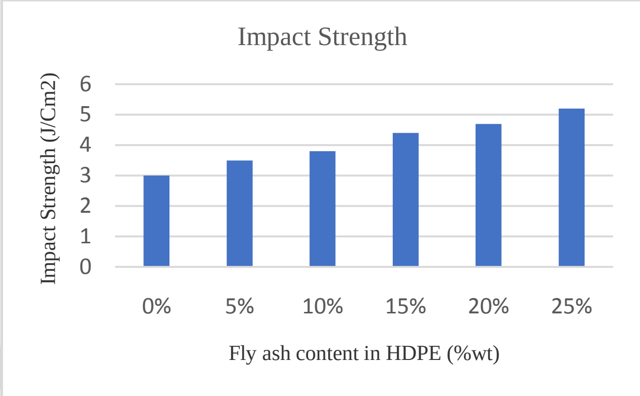

Figure 4.3. Effect of fly ash content on Impact Strength

4.4. Flexural Strength:

The effect of fly ash content on the flexural strength of the composite is shown in Figure 4.4. The result shows that the flexural strength of the composites increases with the increase in fly ash content up to 20%. This is due to the good bond achieved between the mixture HDPE and fly ash. when the fly ash loading increases, the flexural strength gradually increases and this could be also due to the increase in resistance to shearing in the composites structure probably because of the presence of fly ash.

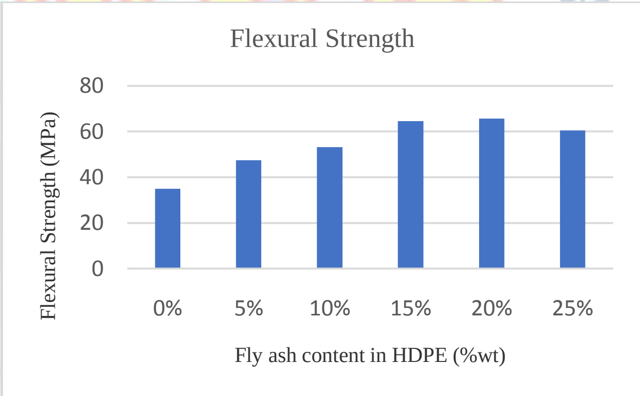

Figure 4.4. Effect of fly ash content on Flexural Strength

4.5 Water Absorptivity:

Results obtained from water absorption test indicated that water absorptivity of composite samples was slightly increased with the increment of fly ash content in HDPE. This is due to the presence of higher contents of filler loading in the composites that can absorb more water. From the results of this test, it can be concluded that effect of moisture is present on composites filled with fly ash due to the property of water absorptivity. High water absorption rate can decrease the strength of the materials. Here, there is no noticeable change in water absorptivity with varying fly ash proportion.

5. CONCLUSIONS

The die for making polymer composites was made and HDPE-fly ash composites were successfully fabricated by compression molding technique, in conjunction with hydraulic press. The mechanical properties were improved with addition of fly ash content. It is found that the highest tensile strength of 34.2 MPa was obtained for 10% fly ash content in HDPE composite which was 50% more than pure high-density polyethylene. The hardness of the composite was found to increase with the increase of fly ash content in HDPE. It is shows that the highest flexural strength of 65.7 MPa was obtained for 20% fly ash content in HDPE which was 80% more than pure high-density polyethylene. Impact strength of the composite was also increased with increment of fly ash content which is nearly 73% more than pure HDPE strength. Water absorption rate of composite was slightly increased with increase of fly ash content in HDPE composites. The result of the present work reveals that fly ash can be used as filler material in HDPE matrix, which will reduce cost and give environmental benefits.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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