Reinforcement of Lime Ash Particles in LDPE

N. Khan*, Z. Ahmed, M.A. Wasif and A. Nafees

Polymer and Petrochemical Engineering Department, NED University of Engineering & Technology, Karachi, Pakistan

Abstract: This study presents findings from an experimental investigation on the reinforcement of Lime ash particles (LAP) synthesized from coal fly ash, CaO, and $CaSO_4$ in Low density Polyethylene (LDPE).

The Lime ash particles are synthesized by reinforcing 0 to 30 weight percentages of LAP in virgin LDPE using compression moulding. The mechanical properties of composites are studied and results showed that by adding LAP in LDPE as filler the Tensile Strength and Impact Strength of the composite decreases due to poor interfacial bonding between filler particles and LDPE but Hardness and Flexural Properties increases due to improved properties of surface.

Keywords: Lime ash particles, fillers, reinforcement, LDPE, polymer.

1. INTRODUCTION

Low density polyethylene resin is a versatile polymer, but due to its low strength, stiffness and poor heat resistance, its applications are limited. To overcome these drawbacks and to prepare composite with improved properties, fillers are incorporated into the matrix.

Reinforcing fillers are widely used to improve the properties of plastics, such as the strength, rigidity, durability, and hardness [1] and they also provide significant cost reduction. Numerous fillers like fly ash, mica, talc, calcium carbonate, hollow glass bead, calcium sulphate, calcium hydroxide, carbon black graphite, rubber etc. have been incorporated in polymer matrix with the advent of plastics to enhance properties of the polymer and reduce the cost [2].

Fly ash is produced by the combustion of coal. According to the chemical composition it belongs to the multicomponent systems with SiO_2+ Al_2O_3+ Fe_2O_3 in major proportion [3]. The compounds, Calcium Sulphate and Calcium Oxide occur naturally and are widely available throughout the world. Recent research has focused on synthesizing different types of calcium-based LAP from mixtures of coal fly ash/$Ca(OH)_2$/CaO/$CaSO_4$. The use of coal fly ash as the base material in synthesizing LAP is attractive both economically and environmentally. Previous studies have shown that fly ash when added as filler shows promising results in plastics.

Samson *et al.* studied the synergetic effect of calcium carbonate (CC) - fly ash (FA) hybrid filler particles on the mechanical and physical properties of low density polyethylene (LDPE). Low density polyethylene was filled with varying weight percentages of FA and CC using melt casting. Composites were characterized for mechanical, thermal, microstructural and physical properties. Results showed that the flexural strength increases with increases in FA content of the hybrid filler. The 20wt % FA and 30wt% CC with higher density of (1.78 g/cm^3) is found to be the optimum combination. An increase of 7.27% in micro-hardness over virgin polyethylene is obtained in composites with 10 wt% FA and 40 wt% CC [4].

Iftikhar *et al.*, studied the mechanical properties of High density Polyethylene in which the particle sizes and concentrations of fly ash were varied upto 40% by weight. The composites and specimens were prepared by using twin screw extruder and injection moulding machine respectively. The tests were conducted for the determination of Tensile, Flexural and Impact properties and it was found that tensile, flexural strengths and moduli were increased by the addition of fly ash. The Tensile elongation was reduced at fly ash concentration greater than 10% drastically. The impact resistance was decreased up to 15 % by addition of fly ash concentration and did not show significant change in further addition of fly ash. Composites prepared with smallest size of fly ash particles showed better results in enhancing strength and relative elongation [5].

The aim of this study is to investigate the effect of Lime Ash Particles, on mechanical properties of LDPE, varying ratios of filler were incorporated into the LDPE matrix.

2. EXPERIMENTAL METHODOLOGY

2.1. Raw Material

Calcium Sulphate, Calcium Oxide, Fly Ash (Composition: SiO_2, Al_2O_3, Fe_2O_3, CaO, K_2O, MgO, and C) and virgin LDPE.

*Address correspondence to this author at the Polymer and Petrochemical Engineering Department, NED University of Engineering & Technology, Karachi, Pakistan; Tel: 99261261 Ext 2649; E-mail: nadiakhan@neduet.edu.pk

ISSN: 1814-8085 / E-ISSN: 1927-5129/18

2.2. Specimen Preparation

The experimental program comprises of two main steps:

i) Synthesis of lime ash particles.

ii) Reinforcement in LDPE.

In the first step, lime ash particles were synthesized by adding 19 gm of CaO in 100 ml of water and mixed thoroughly in beaker. Then the mixture was heated in round bottom flask at 65 ^{o}C .After that, 58 gm of Fly ash and 23 gm of Calcium Sulphate were added and slurry was heated at 95 ^{o}C for 2 hrs. After heating, the slurry was filtered to remove water. The mixture was then dried at 150 ^{o}C in an oven under vacuum condition.

In the second step, synthesized lime ash particles and LDPE were added to mould in a quantity as described in Table **1**. The mould was placed in compression moulding machine at 130 ^{o}C at a pressure of 120 bar. The sample was then allowed to cool for 2 hrs at room temperature.

Compositions of samples are mentioned in Table **1**

Table 1: Composition of Samples

Sample	LAP (mass %)	LDPE (mass %)
LAP 10	10	90
LAP 20	20	80
LAP 30	30	70

3. MECHANICAL PROPERTIES

The mechanical properties are often the most important sources to make a decision about product specifications. The selection of material mostly depend on these properties, such as tensile strength, hardness, flexural strength and impact strength. All the samples were subjected to the following tests:

3.1. Tensile Strength

Tensile test was carried out on Universal Testing Machine (UTM Zwick Roell, 2005).

The sample was stretched in a UTM machine. The stretched sample was used to determine the tensile strength, elongation and tensile modulus. The sample was clamped at both ends and stretched until it breaks.

The tensile strength was determined of the samples with 50 mm x12 mm x 5 mm dimensions (Type V dumbbell). The samples were tested at a gauge length of 50 mm and a strain rate of 20mm/min as per ASTM D638. Four specimens were tested for each composition as mentioned in Table **2**.

Table 2: Specimen Composition for Tensile Test

Sample	LDPE gm	Filler gm
LAP 0	10	0
LAP 10	9	1
LAP 20	8	2
LAP 30	7	3

3.2. Flexural Properties: (ASTM D790)

Flexural Test was performed to determine the combine effect of the stresses applied on the sample (tensile, compressive and shear stresses) under flexural loading.

The specimens were fabricated according to the compositions as mentioned in Table **3**. The fabricated specimens of 5 mm thickness, 12 mm width with a gauge length of 50 mm were tested were tested using 20KN capacity UTM, with cross head speed of 20mm/min.

Flexural Strength and Flexural Modulus were determined. The average values of two samples were reported in the result. Three point bend test was performed to determine flexural modulus where the sample was placed horizontally and the force was applied in the mid of the sample creating a “v” shape and the flexural properties were determined.

Table 3: Specimen Composition for Flexural Modulus

Sample	LDPE gm	Filler gm
LAP 0	7	0
LAP10	6.3	0.7
LAP 20	5.6	1.4
LAP 30	4.9	2.1

3.3. Hardness: (ASTM E 18, ISO 2039)

Hardness test was performed by using Rockwell hardness tester Shore Durometer. The hardness test measures the penetration of the indenter under specified conditions.

The specimen with 6 mm thickness was used for the test with steel nob as an indenter. The specimen was placed on a surface and the indenter was pressed on the specimen to measure the hardness on the scale (penetration of the indenter on the specimen). Composition of the specimen prepared for Hardness test is shown in Table **4**.

Table 4: Specimen composition for Hardness Test

Sample	LDPE gm	Filler gm
LAP 0	5	0
LAP10	4.5	0.5
LAP 20	4	1
LAP 30	3.5	1.5

3.4. Impact Test: (ISO 179)

Impact test was used to determine the impact strength of the material. Impact test measures the toughness of material. Toughness of a material is the ability of material to absorb energy in it's plastic deformation.

The test was performed by using Advanced Universal Pendulum Impact Tester Version 1.08.

The rectangular specimen with 50 mm length, 5 mm thickness and 12 mm width was tested. A hammer of 0.905 kg was used to hit the un-notched sample with a velocity of 3.46 m/s to break the specimen. The energy absorbed by the specimen was calculated. Composition of the specimens that were prepared for impact test is mentioned in Table **5**.

Table 5: Specimen Composition for Impact Test

Sample	LDPE gm	Filler gm
LAP 0	7	0
LAP 10	6.3	0.7
LAP 20	5.6	1.4
LAP 30	4.9	2.1

4. RESULTS & DISCUSSION

The mechanical properties for LAP and LDPE are depicted in Figures **1** to **4**. It is evident that Flexural Modulus and Hardness are increasing by increasing the percentage of reinforcement but the Tensile strength and Impact strength are decreasing.

4.1. Tensile Strength

The Figure **1** shows the effect on tensile strength on LDPE by the addition of lime ash particles. It is evident that tensile strength decreases with increase in percentage of lime ash particles because the filler particles agglomerates which decrease the dispersion, reduce the compatibility resulting in poor interfacial adhesion and poor mechanical properties [7].

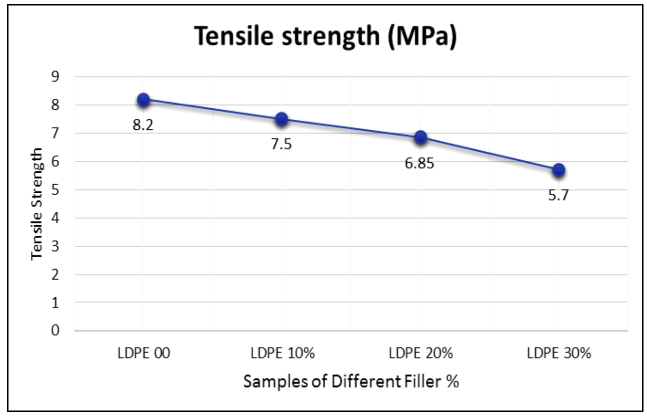


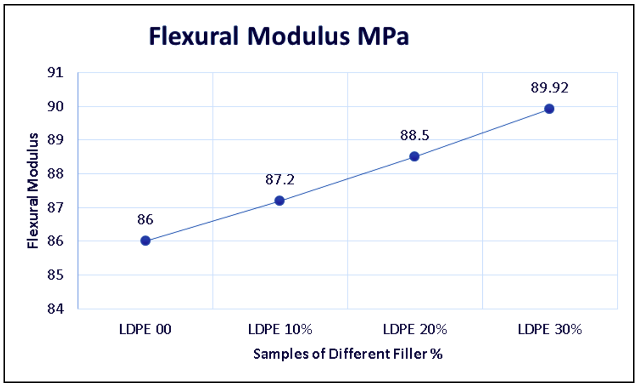
Figure 1: Tensile strength.

4.2. Flexural Properties

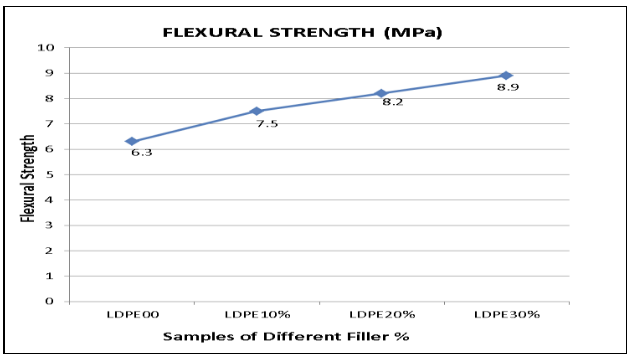
The Figure **2a** and **b** shows the effect of LAP on LDPE. The results indicate that increasing mass percentage of lime ash increases its Flexural strength and Modulus. It clearly indicates that filler enhanced the surface property of composite and it resists deformation by penetration that means reinforcement of lime ash particles increased the abrasion resistance of sample as well as wearing resistance. Since the surface property of the reinforced samples increased it shows resistance to the bending stress hence having higher flexural strength as compared to virgin LDPE. The same result was discussed by the author that the increase in Fly ash to polyethylene leads to increase in Flexural strength and modulus [4]. Gummadi *et al.* also reported that flexural modulus increases for smaller filler loadings [6].

4.3. Hardness Test

Figure **3** shows that by increasing the filler mass percentage from 0% to 30% hardness of composite increases, as filler enhanced the surface property of composite and resist deformation by penetration, that means reinforcement of lime ash particles reduces the elasticity of polymer chains resulting to a more rigid polymer [7-10].



(**a**)



(**b**)

Figure 2: (**a**) Flexural Modulus. (**b**) Flexural Strength.

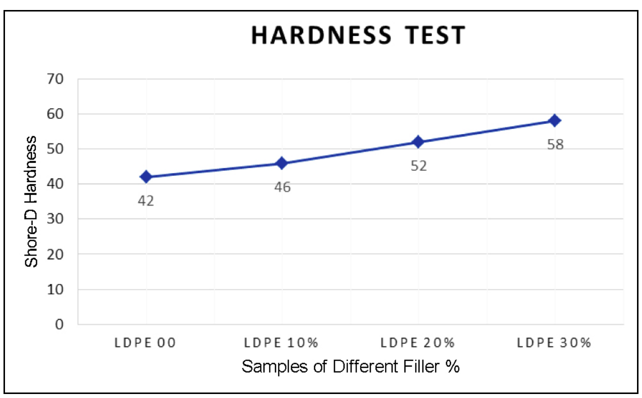


Figure 3: Hardness Test.

4.4. Impact Strength

The effect of impact strength on specimens are shown in Figure **4**. It is evident from the results that impact strength decreases by increasing the amount of filler in LDPE loading due to formation of voids resulting in poor interfacial bonding between the filler and the polymer matrix [5].

5. CONCLUSION

The present investigation reports the compatibilization efficiency of Lime ash particles in

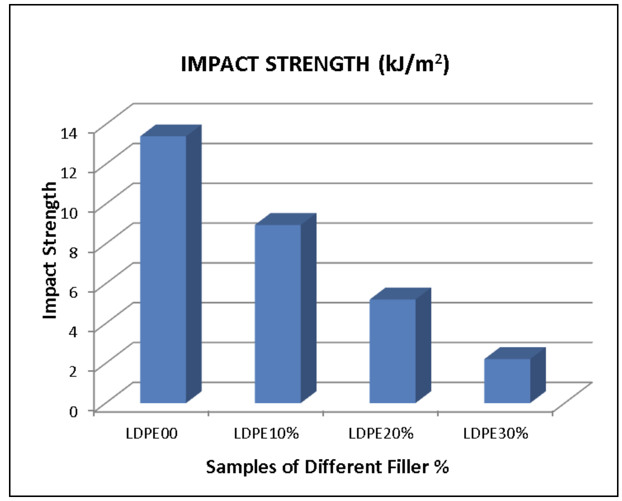


Figure 4: Impact Strength.

LDPE by varying LAP from 10 to 30 wt %.It is evident from the mechanical properties that LAP improves the Hardness and Flexural Properties of LDPE because surface properties of the composite have improved but Tensile Strength and Impact Strength decreases because of poor interfacial bonding between Filler and LDPE matrix.

ACKNOWLEDGEMENTS

We would like to thank Dr Kausar Ali Syed, (Chairperson PPD) for his support. We would also like to acknowledge Farzeen Ahmed and Hasan Hamid for their support in preparing the samples.

REFERENCES

[1] DeArmitt C. Functional fillers for Plastics‖ "Applied Minerals Inc, 110 Greene St, Suite 1101, New York, NY 10012, USA." 2011.

[2] Pandian NS. Fly ash characterization with reference to geotechnical applications. Journal of Indian Institute of Science 2004; 84(6): 189-216.

[3] M.V Mechanical and thermal characteristics of high density polyethylene-fly ash cenopheres composites. Material and Design 2010; 2051-2060.

[4] S.A Characterization of LDPE Reinforced with Calcium Carbonate—Fly Ash Hybrid Filler. Journal of Minerals & Materials Characterization and Engineering 2014; 2: 334-335. https://doi.org/10.4236/jmmce.2014.24038

[5] Ahmad I. Properties of Fly Ash Filled High Density Polyethylene. Journal of Minerals & Materials Characterization and Engineering 2010; 9: 183-198. https://doi.org/10.4236/jmmce.2010.93016

[6] Gummadi *et al.* Evaluation of Flexural properties of fly ash filled polypropylene composites. International Journal of Modern Engineering Research 2: 2584-2590

[7] Idowu IA. Effects of filler on some mechanical properties of recycled low-density polyethylene composites, Proceedings of the OAU Faculty of Technology Conference 2015.

[8] Sukanya S. Mechanical Dynamic Mechanical, and Thermal Characterization of Fly Ash and Nanostructured Fly

Ash-Waste Polyethylene/High-Density Polyethylene Blend Composites, Polymer composites 2016.

[9] Atikler U, *et al.* Mechanical and Morphological properties of recycled high density polyethylene, filled with calcium carbonate and flyash. Appl Polym Sci 2006; 102: 4460. https://doi.org/10.1002/app.24772

[10] Bose S, Mahanwar PA. Effect Of Flyash On The Mechanical, Thermal, Dielectric,Rheological And Morphological Properties Of Filled Nylon 6. JMMCE 2004; 3: 65. https://doi.org/10.4236/jmmce.2004.32007

Received on 12-03-2018 Accepted on 21-03-2018 Published on 06-04-2018

https://doi.org/10.6000/1927-5129.2018.14.17