



A Study of the Effect of TiO_2 , CaCO_3 and Al_2O_3 on Mechanical Properties of LDPE Polymer Composites Fabricated by Injection Moulding Technique

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Abstract

Due to their cost effectiveness, greater strength and ease of fabrication, polymer composites are noticeable candidate almost in all areas. However, when they are used in their original form they possess very low wear resistance and hardness. The present investigation gives information on mechanical properties of polymer matrix composites where LDPE (Low density polyethylene) is used as polymer matrix and TiO_2 , Al_2O_3 and CaCO_3 are used as reinforcements. The samples were prepared according to ASTM standards by injection moulding machine with varying percentage of reinforcements in polymer matrix. Tests viz., tensile, flexural impact are carried out.



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Introduction

Polymer composites over the decades had more attentions because of their major improvement in mechanical properties. By additions compounds such as Aluminium Oxides (Al_2O_3)⁴, glass fibers⁵, carbon nanotubes and carbon black⁶, to polymers is going to produce new polymer composites with enhanced mechanical and wear resistance properties in addition to being comparatively cost-effective compared to their original corresponding

item. This may result in new industrial uses. These reinforcements are going to effect the properties, surface characteristics and bonding of polymer will leads to enriched properties for industries uses⁷. These additives will help to withstand some of the applied tension to the polymer matrix leading to improved tensile properties of the finished product. Polyethylenes are polymer materials which are easily manufactured and low cost which can be handled at temperature of 140-249 °C¹. Polyethylenes are of

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The present work is analysis of CaCO_3 , Al_2O_3 & TiO_2 reinforced LDPE composite, which are moulded into the shape of the die prepared according to ASTM standard using injection moulding machine on a low budget, which can be functioned with a smaller amount of effort. The prepared specimens are tested for various mechanical properties.

There are three type of polyethylenes are available. In which UHMWPE is one which have poor properties like ductility and fracture toughness. But other two polyethylene, LDPE & HDPE have good cross linking property which results in their improved molecular structures and mechanical properties. Both LDPE & HDPE have the similar properties. Therefore, in this investigation low density polyethylene (LDPE) used as polymer matrix material. LDPE have poor mechanical properties and which can be enriched by adding metallic or/and ceramic in the polymer matrix. Hence, in the present study alumina (Al_2O_3), calcium carbonate (CaCO_3) and titanium oxide (TiO_2) were used as the reinforcing materials and all the reinforcing materials are in powder form with 325 mesh size. For the perfect results different compositions used for the fabrication of the samples.

Extruder is used for composition preparation and Injection moulding machine is used for specimen's preparation according to ASTM standard. For composition (LDPE, TiO_2 & Al_2O_3) preparation with variation in LDPE, Al_2O_3 , and TiO_2 , remains constant

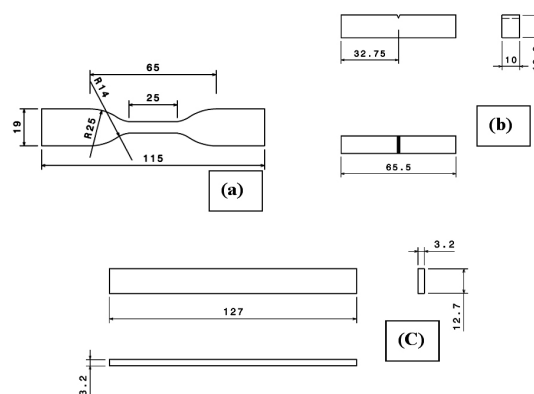


Fig. 1a,1b & 1c: specimen dimensions (mm) for Tensile strength, Impact strength and Flexural strength test

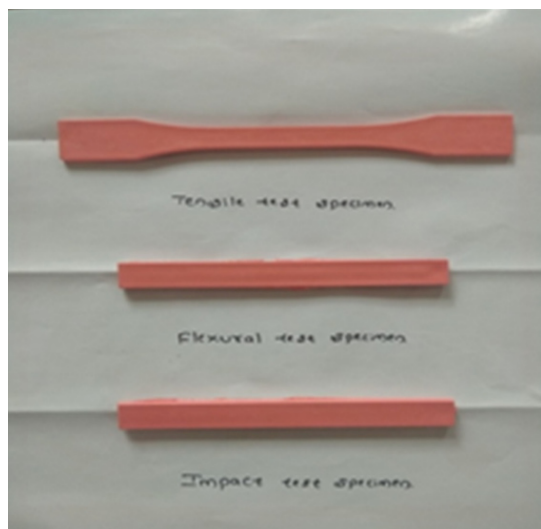


Fig. 2: Prepared specimens according to ASTM standard for testing purpose

in all specimens. LDPE which is in granular form and TiO_2 & Al_2O_3 which are in powder form are mixed with measured amount and transferred into hopper of the extruder. The material is slowly melted by the mechanical energy generated by turning screws and by heaters arranged along the screws. The molten polymer composition then passes through die, which give shape to the polymer composite and hardens during cooling. Obtained composites is made into small pieces using pelletizer and transfer all pieces into hopper. Composition pieces are fed by ram from a hopper into a heated barrel. As the granules are slowly moved forward by a screw-type plunger, the pieces are moved into a heated chamber ($150\text{--}250^\circ\text{C}$), where they get melted. As the plunger advances, the melted pieces are forced through a nozzle into the mould where it takes the shape of mould cavity as defined by ASTM standard⁸⁻¹⁰. It saves the time and composite material. The same steps are followed to prepare (LDPE, TiO_2 & CaCO_3) composition. Figure 3 show the Extruder and Figure 4 shows injection moulding machine with mould cavity.

Tensile, Flexural and Impact test were performed in the KONKAN SPECIALITY POLYPRODUCTS PRIVATE LIMITED testing laboratory, Mangalore, Karnataka. Tensile testing machine make had LOADCELL 20 kN and Test speed 5 mm/min. Flexural testing machine make had LOADCELL



Fig. 3: Extruder



Fig. 4: injection moulding machine with mould cavity

20kN and Test speed 14.93 mm/min. Impact test machine make HIT50P with Nominal work capacity: 7.5 J Theoretical impact velocity: 3.807 m/s.

Results and Discussions

This investigation illustrates the mechanical behavior of LDPE + Alumina/Calcium carbonate + Titanium Dioxide polymer composites. The injection moulding machine was used for fabricating samples and ASTM standards were followed to carry out the test. Table 2 indicates the designation of each composite which will be used throughout this paper.

Tensile strength

Tensile strength for the prepared polymer composites was carried out and results are represented in bar chart as shown in figure 4. In one composition alumina (Al_2O_3) is varied from 8% -16% with increase of 4% in a step and TiO_2 remains constant of 10% and in other composition calcium carbonate(CaCO_3)

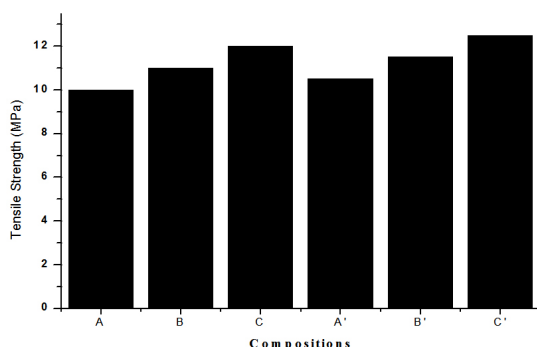
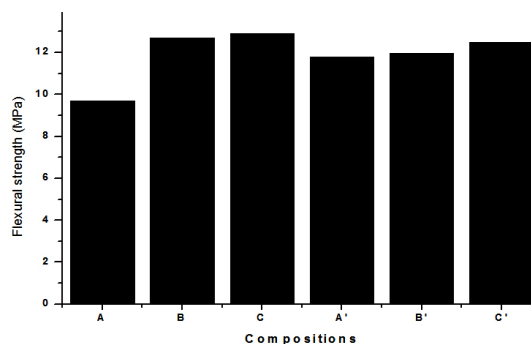
Table 2: Designations and detailed compositions of the composites

Composition	Designation
LDPE + 10%TiO ₂ + 8%Al ₂ O ₃	A
LDPE + 10%TiO ₂ + 12%Al ₂ O ₃	B
LDPE + 10%TiO ₂ + 16%Al ₂ O ₃	C
LDPE + 10%TiO ₂ + 8%CaCO ₃	A'
LDPE + 10%TiO ₂ + 12%CaCO ₃	B'
LDPE + 10%TiO ₂ + 16%CaCO ₃	C'

is varied from 8%-16% with increase of 4% in a step and TiO₂ remains constant of 10%. Figure 4 shows that tensile strength increases with the increase in the amount of alumina because of its hard and stiff nature. Hence capacity of the composite increases to carry load. 12MPa of C composite shows the greater value among other two composites. In case of (LDPE+ TiO₂ + CaCO₃) composition tensile strength increases with the increase in the amount of calcium carbonate due to its hard nature¹ and values are represented in bar graph as shown in figure 5. when compared two compositions i.e. one with Al₂O₃ and other with CaCO₃, Composition with C' shows 12.5Mpa which is greater than alumina composite.

Flexural Strength

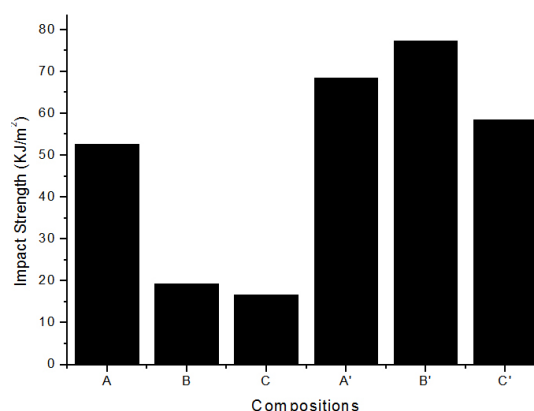
Flexural strength for the prepared composites was conducted and values are represented in the bar chart as shown in figure 6. In one composition alumina (Al₂O₃) is varied from 8% -16% with increase of 4% in a step and TiO₂ remains constant of 10%

**Fig. 5: Tensile strength of composites having different percentage of reinforcing material****Fig. 6: Flexural strength of composites having different percentage of reinforcing material**

and in other composition calcium carbonate(CaCO₃) is varied from 8%-16% with increase of 4% in each step and TiO₂ remain constant of 10%. Flexural property increases with the increase in the amount of alumina, which offers resistance to deformation because of its hard and stiff nature¹⁻². Hence flexural property increases. 12.9MPa of C composite shows the greater value among other two composites. In case of (LDPE+ TiO₂ + CaCO₃) composition flexural property increases with the increase in the amount of calcium carbonate due to its hard nature and values are represented in bar graph as shown in figure 5 The maximum Value obtained was 11.95 MPa for C'.

Impact strength

Impact strength is the capability of the material to withstand a suddenly applied load and it is calculated by noticing the energy observed, for approximating the impact strength. Impact strength

**Fig. 7: Impact strength of composites having different percentage of reinforcing material**

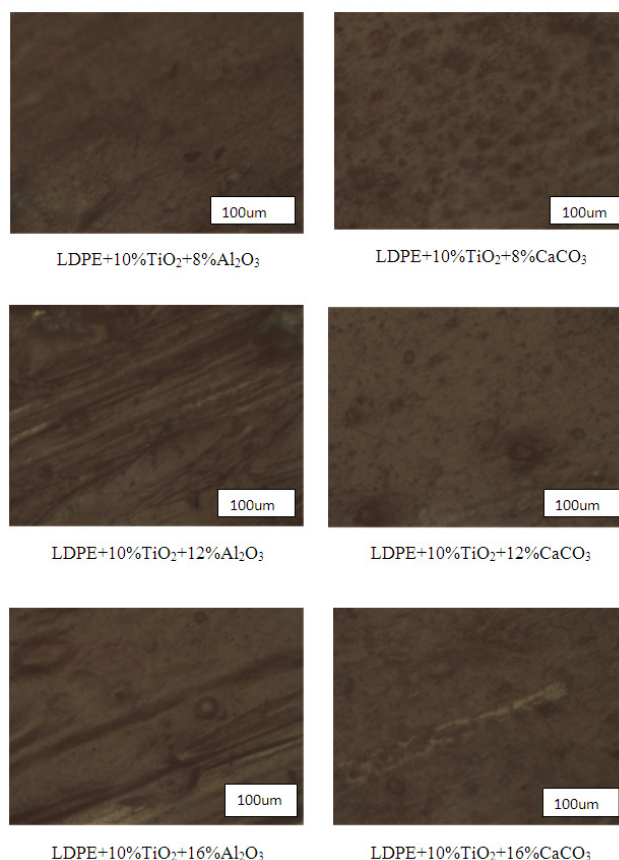


Fig. 8: Optical microscope images of Composites

of composites (LDPE+ Al₂O₃ + TiO₂) are shown in figure 7. Impact strength decreases with increase in amount of alumina in composites this is due to reduction in ductility because of hard and stiff nature of alumina. 52.64kJ/m² for C shows greater value of impact strength among other two composites which contains alumina. In case of Calcium carbonate impact strength initially increases and decreases as increase in calcium carbonate in composition due its hard and stiff nature. The maximum impact strength obtained was 77.41kJ/m² for C'.

Microstructure Analysis

All the composites are observed under the optical microscope for mixing of alumina and calcium carbonate in polymer matrix. Figure 8 shows the images of composites under 20X magnification. From images it is clear that particles are spread evenly in the polymer matrix and there are surface imperfections are seen. These surface imperfections

are due to mould defects. Enhanced mechanical properties are achieved due to evenly spread and bonding between added particles and polymer matrix.

Conclusion

Present investigation has been made to produce a polymer matrix composites for industrial and technological applications. Based on the results, conclusions are drawn.

1. Tensile and flexural strength increases with increase in the amount of alumina and Calcium carbonate in the polymer matrix composite.
2. Due to increase in the ductility as there is an increase in amount of alumina and calcium carbonate in composites, impact strength decreases.
3. Optical microscopy images show some

surface imperfections in produced specimens. By results, an evenly spread of particles and bonding between added particles and polymer matrix is seen.

Defects free specimens can be prepared using injection moulding machine.

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Conflict of Interest

The author(s) declare(s) that there is no conflict of interests regarding the publication of this article.

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