Preparation and Tribological Characterization of Linear Low Density Poly-Ethylene Sea Shell (LLDPE/Sea Shell) Bio Composite

Gajendra Mundel, M. Ravi Sankar*

Department of Mechanical Engineering, IIT Guwahati, Guwahati, 781039
m.gajendra@iitg.ernet.in,*evmrs@iitg.ernet.in

Abstract

In the current work, polymer bio-composite is fabricated using linear low density polyethylene (LLDPE) as base polymer with varying weight percentage (wt%) of sea shell powder/particleas reinforcement. The average sea shell particle size used in the work is about 75 µm. The reinforcement wt% varied is 5, 10, 20, 30, and 40 to check the various tribological properties. Pin-on-disc tribometer (Hardened AISI 4340 steel disc, abrasive disc) is used to check various tribological properties such as wear, frictional force and average coefficient of friction. Apart from tribology, water absorption test of these compositions were studied. Experimental results shows decrease of coefficient of friction and wear with increasing filler content while water absorption behavior of composites increases as function of time of exposure studied increased with increasing filler content.

Keywords: LLDPE, bio-composites, sea shells, tribology

1. Introduction

Thermoplastics are polymer which becomes soft and hard when heated and cooled respectively. These can be remolded in many shape for times. The selection of thermoplastic composites for specific composite application is determined by the processing history, mechanical, tribological properties, thermal stability, chemical properties and cost (Nwanonenyi, et al. 2013). Linear low density polyethylene (LLDPE) is a thermoplastic and is used in many applications. The predominant application of LLDPE is due to its toughness, flexibility, relative transparency, low moisture absorption, good dielectric characteristics, environmental stress cracking, excellent heat seal strength, and chemical as well as corrosion resistance (Nwanonenyi, et al. 2013). In order to enhance further the physical and tribological properties some additives can be incorporated into LLDPE polymer. This study focused on the fabrication and effect of filler powder on the tribological properties of seashell powder filled LLDPE (Nwanonenyi, et al. 2013). Different authors tried different types of the polymers such as polypropylene (Neogi et al., 2003, Amana et. al., 2012, Amana et. al., 2013), low density polyethylene (Shnawaet. Al., 2011) with sea shell particles to improve various properties. At the same time many researchers also tried different types of reinforcements such as carbon nanotubes (Gandhi et. al., 2013), clay (Durmus et. al., 2008) and zeolite (Biswas et. al., 2003) with LLDPE.

Wear, friction force, coefficient of friction of seashell filled LLDPE composites were studied against steel and abrasive paper. It was found that wear, friction force and coefficient of friction decreases with increasing filler content in LLDPE against steel disc. However against abrasive paper the optimum concentration of seashell in LLDPE was found to be 20 wt. %, where wear and coefficient of friction were decreased by 5.35 and 31.35 % respectively.

2. Experimentation

2.1 Materials

In the current study, linear low density polyethylene (LLDPE) is used as matrix material. LLDPE used in this study possess melt flow index of 5gm/10min and density 0.934gm/cm$^3$. Filler material used in this work is micro particles/powder of sea shells.

2.2 Preparation of sea shell powder/particles

![Figure 1 Preparation procedure of sea shell powder from raw sea shells](image-url)
2.3 Fabrication of composite

In the present work, LLDPE-Sea shell bio-composites are fabricated by varying different weight percentage of filler material (sea shell).

The sea shells powder obtained after sieving were dried in oven. Now the composites of different (5,7.5,10,20,30,40,50) weight percentage (%) of sea shell were prepared. For this first the sea shell powder is dispersed in water in a pot, then that is heated up, after some time when water starts boiling LLDPE is poured in the hot water and sea shell powder mixture. The heating is continued until whole water get evaporate, during vaporisation of water sea shells particles got adhered to LLDPE granules. Now the sea shells adhered LLDPE is poured into Twin Screw Extruder at zone temperature of 195°C, 210°C, 220°C, 220°C, screw rotating speed of 150rpm and feed rate of 20rpm to get homogeneous mixture of sea shells and LLDPE. Fabrication of LLDPE-sea shell composites is explained in figure 2.

![Fabrication Procedure Diagram]

**Figure 2 Preparation procedure of composite granules for making bio-composite**

2.4 Tribology test

Dry sliding wear and coefficient of friction tests were conducted on pin-on-disc friction and wear testing machine (DUCOM TR201). Sample is run against AISI 4340 steel disc containing 0.59% carbon, 0.25% silicon, 0.8% manganese, 1.02% chromium, 0.30% molybdenum, 1.50% nickel of hardness 305 Hv for 30 minutes. After each observation the disc was cleaned using acetone. Sample run against steel disc will give the adhesive wear. The tests were conducted at 2kgf load and 150 rpm. Figure 3 shows the wear testing machine used for tribology testing. Weight loss (Δw) in abrasive wear was calculated by weighing sample before and after test. Volumetric wear loss was calculated by dividing weight loss by density (d) of sample calculated by weighing and dividing that by samples volume calculated from known dimensions of sample using vernier calliper. Volumetric wear loss per sliding distance (m³/m) was calculated by just dividing volumetric wear loss (m³) by sliding distance that can be calculated as follow:

\[
\text{Sliding distance} = \frac{\text{Volumetric wear loss}}{\text{Distance}} \tag{1}
\]

Where D = diameter of disc, N = rpm of disc, t = time of run.

### Table 1 Formulation of LLDPE and Sea shell bio composite

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>LLDPE(%)</th>
<th>Sea Shell(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLDPE/SS-100/0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>LLDPE/SS-95/5</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>LLDPE/SS-90/10</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>LLDPE/SS-80/20</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>LLDPE/SS-70/30</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>LLDPE/SS-60/40</td>
<td>60</td>
<td>40</td>
</tr>
</tbody>
</table>

![Tribology Tester Diagram]

**Figure 3 Overview of pin on disc tribology tester (DUCOM Model No. TR-201)**

2.5 Water Absorption Test

Water absorption test was done by total immersion of three specimens in distilled water at room temperature. The water absorbed was measured by weighing the samples at regular intervals with the help of digital weighing balance. The water adhering on the surface of the specimen was carefully removed using tissue paper, care was taken during the wiping process not to remove the water absorbed by
specimen. The percentage of water absorption was calculated using the expression:

\[ w(\%) = \left( \frac{w_f - w_i}{w_i} \right) \times 100\% , \quad (2) \]

where, \( w_f \) and \( w_i \) are wet and dry weight of specimens respectively.

3 Results and discussion

3.1 Tribology against the Stainless steel disc

From figure 4 it is clear that the wear decreases with increasing the filler content in LLDPE. This is attributed to the reason that with increasing filler content direct contact between steel disc and polymer matrix will reduce. Figure 5 and figure 6 shows the decrement in and friction force coefficient of friction respectively with increasing the filler content, this is attributed to the reason that there will be less contact between polymer and disc so the polymer will not stick that much to disc to cause resistance to sliding and also filler particles will come between disc and polymer matrix and act as roller so that there will be smooth sliding motion between disc and polymer matrix.

3.2 Abrasive based tribology of bio-composite

Figures 7 to figure 10 shows the trends of wear, friction force and average value of coefficient of friction respectively for abrasive wear testing against abrasive (emery) sheet.
Here it is observed that with increasing the filler content up to 20% both wear and friction force decreases but when filler content was increased beyond 20% both wear and friction force starts increasing for 30 and 40% which may be attributed to the increased hardness that will cause resistance to wear in abrasive wear so the friction force increases.

**Table 2** Abrasive wear loss of LLDPE/Sea shell bio-composite for different filler loading

<table>
<thead>
<tr>
<th>Filler Content (%)</th>
<th>Weight loss (Δw)</th>
<th>Volumetric Wear = Δw/d (m³)</th>
<th>Wear (m³/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.04954</td>
<td>0.052831</td>
<td>0.000449</td>
</tr>
<tr>
<td>5</td>
<td>0.04971</td>
<td>0.052419</td>
<td>0.000445</td>
</tr>
<tr>
<td>10</td>
<td>0.0499</td>
<td>0.052033</td>
<td>0.000442</td>
</tr>
<tr>
<td>20</td>
<td>0.0524</td>
<td>0.050081</td>
<td>0.000425</td>
</tr>
<tr>
<td>30</td>
<td>0.0564</td>
<td>0.050633</td>
<td>0.00043</td>
</tr>
<tr>
<td>40</td>
<td>0.06347</td>
<td>0.053055</td>
<td>0.000451</td>
</tr>
</tbody>
</table>

### 3.3 Water Absorption Test

Figure 11 shows the variation in % water absorption with different filler content with time of exposure. It is observed that composites with higher filler content have higher water absorption capacity. This is because the presence filler particles increased pores within the composite, thereby increasing the water absorption capacity of the composite and also may be due to the reason that as the filler content increases, the formation of agglomerations increases due to difficulties of achieving a homogeneous dispersion of filler content at higher filler content within matrix. The agglomerations of filler in composites increases water absorption of the water.
4 Conclusion

From the present study it is concluded that LLDPE/Sea shell bio composite is fabricated using twin screw extruder. Wear against steel decreases with increasing the filler content in LLDPE, decrease in wear with addition of sea shell show the less adhesive nature of it with increasing temperature. Decrement in friction force & COF with increasing the filler content were observed when samples were run against steel disc. When samples were run against abrasive paper wear, friction force and coefficient of friction all three parameters decreases with increasing filler content up to 20 wt. %, after this increasing filler content wt. % in LLDPE increases all three parameters.

Composites with higher filler content have higher water absorption capacity which is due to the formation of agglomerations increases due to difficulties of achieving a homogeneous dispersion of filler content at higher filler content within matrix.

References


Ashok Gandhi, R., Palanikumar, K., Ragunath B. K., PauloDavim, J., (2013) Role of carbon nanotubes (CNTs) in improving wear properties of polypropylene (PP) in dry sliding condition; Materials and Design, 48,pp 52-57


