Effect of blend composition on abrasive wear of red mud filled PP/LDPE blends

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Effect of blend composition on abrasive wear behaviour has been studied for red mud (RM) particulate filled blends of isotactic polypropylene (PP) and semicrystalline low density polyethylene (LDPE) by using two body abrasion tester. Wear rate has been correlated with the composition and structure of the studied systems. Wear rate decreased with the increase of PP content in those blend compositions where PP form the matrix, whereas reverse was observed in case of compositions in which LDPE forms matrix. Mechanism of this behaviour has been explained on the basis of X-ray diffraction studies and interaction amongst the constituents of composites.

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Chemical resistance, high damping properties for low noise emission, ability of dry sliding etc. makes polymers and their blends suitable for wear applications. The problem associated with polymers lies in their low operating temperature due to which strength goes down owing of creep which occurs under a load. In such cases particulate filled polymers provide a high load capacity. Moreover addition of filler into polymers improves flexural modulus, dimensional stability, heat deflection temperature etc. Fillers reduce wear by modifying the counterphase surface by changing crystalline structure of polymer or by inhibiting the large scale destruction of banded structure. In recent years several studies have been reported to understand the wear behaviour of some selected polymeric systems such as teflon based materials but less attention has been focused on polyolefin blends. These blends have drawn attention of researchers due to the possibilities of improving the performance of materials as well as their recyclability. Mechanical, rheological and morphological properties of red mud particulate filled isotactic polypropylene (PP) / low density polyethylene (LDPE) blends have been reported recently. Red mud is a solid waste material produced by the alumina industries following the Bayer's process. Several studies related to disposal, characterization and utilization of red mud have been reviewed. It has been used as filler material with several polymers and blends to improve their mechanical, thermal and rheological properties. Effect of addition of red mud particles in PP/LDPE blend was studied. Blend ratio of PP/LDPE was fixed at 1.0 and loading of red mud was varied. It was observed that at low concentration of red mud, abrasive wear loss of composites increased with red mud loading. The wear loss however, showed a decreasing trend after a critical loading of red mud in the composites. This improvement was attributed to the increased number of RM particles available on the surface to resist abrasion of polymer. In present paper red mud loading has been kept constant and blend ratio of PP/LDPE has been varied to study the effect of matrix composition on wear properties.

Experimental Procedure

Isotactic polypropylene (density 0.89g/cm³, grade Koylene M0030) from M/S IPCL Baroda, India; low density polyethylene (density 0.91g/cm³ commercial grade) from M/S Monika plastics, Indore, India, RM particles (size< 210 μm) from M/S BALCO, Korba India were obtained for this study. Major chemical constituents of RM particles are SiO₂ 9.16%, Fe₂O₃ 53.97%, Al₂O₃ 14.97%. Mineral phases, chemical composition and structure of RM particles used in this study were re-
ported earlier. A two roll mixing mill was used for mixing of polymers and fillers. The polymers and filler were dried to remove moisture prior to feeding into mixing mill. Temperature of mixing mill was fixed at 170±5°C. The compounded material was removed in the form of thin sheets of 1.0 mm thickness from the rollers. Compounded sheets were hot pressed into 4 mm thick sheets at temperature 180±2°C for one minute at 1.0 MPa pressure by using hand operated, electrically heated compression molding machine. The mould was then cooled to room temperature by circulating the water at 20°C under pressed conditions. The compositions and mechanical properties of composites are listed in Table I.

Abrasive wear tests for evaluating the high stress abrasion resistance of RM filled polymers were conducted on two-body Suga Abrasion tester model NUS1 (Japan). Wear rate was calculated from weight loss measurements by using the formula,

\[ W = \frac{V}{\rho D} \]

where \( \rho \) is the density of composite, \( V \) is weight loss and \( D \) is sliding distance. X-ray diffraction patterns were obtained by Phillips diffractometer Model PW-170.

**Results and Discussion**

Fig. 1 contains plots between wear rate and sliding distance for PP/LDPE/RM systems of different compositions at 1, 3, 5 and 7N applied loads. It is observed that wear rate remained uniform with sliding distance, however it varies with the change in composition of composites. The minimum wear rate was observed for sample A which does not contain LDPE. With the increased amount of LDPE in this system, wear rate increased as observed in Fig. 1a. This reaches to the maximum level in sample D where LDPE concentration is three times to that of PP, however RM particles filled LDPE (sample E) is more wear resistant as compared to sample D which contains 25% PP in the matrix. Similar trends were observed at higher applied loads as shown in plot (b), (c) and (d) of Fig. 1. On comparing Fig. 1a-d it was noticed that each curve belonging to a particular composition becomes distinct from the others, on increasing the applied load. Fig. 1b and c also demonstrate the
Table 1—Composition and mechanical properties of red mud filled PP/LDPE composites

<table>
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<tr>
<th>Sample</th>
<th>Composition</th>
<th>Mechanical Properties</th>
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<td></td>
<td>PP (g)</td>
<td>LDPE (g)</td>
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<tr>
<td>A</td>
<td>100</td>
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</tr>
<tr>
<td>B</td>
<td>75</td>
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<td>C</td>
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<td>D</td>
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wear resistance of various composites as mentioned above. However, scattering of data was observed in Fig. 1a at 1N applied load. This scattering may be attributed to low pressure which is below a critical pressure required for a uniform asperity contact area for a particular sliding speed. Fig. 1d is a plot at 7N and clearly demonstrate that composition 100/0/15 is more wear resistant as compared to others. Wear resistance of PP/LDPE/RM systems studied here varies with the compositions as follows,

100/0/15 > 75/25/15 > 50/50/15 > 0/100/15 > 25/75/15

PP is a wear resistant polymer as compared to LDPE. Wear in PP is caused by the microcutting and ductile tear of PP. Addition of RM particles reduces the wear resistance of PP due to their brittle fracture during abrasive action. Moreover, RM particles do not adhere well with PP and therefore can be removed easily from the surface leaving behind the PP matrix for further cutting on subsequent cycles. Addition of LDPE in PP matrix further deteriorate the wear resistance because of addition of less wear resistant polymer (LDPE). Fig. 1 clearly shows that RM filled PP is more wear resistant as compared to RM filled LDPE. Addition of LDPE decreases wear resistance in all compositions.

An interesting result noticed in these experiments and shown in Fig. 2 is that wear rate not only depends upon compositions but also depends upon structure of composites. With the increase of LDPE content in matrix up to 75 wt%, the wear rate increased but at 100 wt%, the wear rate decreased. This phenomenon is attributed to the phase inversion of matrix and poor compatibility between the two polymers. Both PP and LDPE are incompatible, non interacting polymers and therefore addition of LDPE weakens the structure. At 25 wt% PP in matrix, tensile strength of composites was found to be the lowest (Table 1), whereas at zero wt% PP, the tensile strength was comparatively higher which is an outcome of phase inversion. Moreover, strength of PP is attributed to its crystallinity in absence of strong intermolecular forces. The decrease in crystallinity of PP due to the presence of molten LDPE and RM particles at the time of crystallization of PP, reduces strength of PP which lead to a weaker structure. This is illustrated in Fig. 3 which compares X-ray diffraction patterns, of (a) PP and (b) PP/LDPE (25/75) and (c) PP/LDPE/RM (25/75/15). Sharp peaks on X-ray diffraction patterns of polymers are referred to their crystalline structure whereas diffused peaks are referred to the amorphous structure. The height of the peaks have been correlated with the per cent crystallinity of polymer. In present case four major peaks are observed in addition to several other peaks in X-ray diffraction pattern of PP. Addition of LDPE into PP changes the X-ray diffraction pattern as shown in Fig. 3. Characteristic peaks of semi crystalline LDPE were observed at 21.3° 20 angle. Peak intensity at 17.08° 20 angle was increased on addition of LDPE however intensity of a characteristic peak of PP at 14.18° 20 an-
angle was reduced. The crystallinity of either of polymers does not change significantly on blending but it reduced significantly with the addition of RM particles. Decreased crystallinity which leads to a weaker structure coupled with phase inversion was responsible for a reduced wear resistance of composite. Removal of LDPE from the matrix was easy due to poor adhesion with PP phase, however when RM filled LDPE (without PP) was subjected to abrasive wear, it offered more resistance as compared to the sample D which contained wear resistant PP. In that case PP was spread in isolated globules form and was loosely held with LDPE and therefore removed easily during abrasive action along with RM particles. With the increased applied load, wear rate increased as shown in Fig. 4. This is attributed to asperity contact area which increased with the applied load.

The overall wear rate in general is controlled by the weight per cent of constituent polymers. PP is more wear resistant than LDPE therefore, lowest wear rate has been observed in sample A.

**Conclusion**

This study reveals that the wear resistance of PP/LDPE/RM composites depends upon the constituents composition and structure of composites. Addition of LDPE in red mud filled PP reduced wear resistance in general, however RM particulates filled LDPE was found more wear resistant than 25/75/15 :: PP/LDPE/RM composition due to the phase inversion and presence of incompatible phases.

**References**