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Role of Nano Clay in Improving Wear Properties of Polypropylene in Dry Sliding Condition†

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The friction and wear behaviour of polymer blends and composites are complex when compared to the ordinary materials because the individual components have their unique response towards the friction and wear. Polypropylene-nanoclay composites were prepared using the melt blend method. The sliding wear of polypropylene and nano clay (montmorillonite) blends are evaluated as a function of applied load and composition against a steel counter face in dry condition. Wear performance is investigated and presented in detail. Microstructure and worn surfaces of samples were observed by scanning electron microscope. The wear phenomenon has been discussed on the basis of weight loss and worn surfaces.

Key Words: Polypropylene, Nano clay (montmorillonite), Pin-on-disc, Blend, Microstructure.

INTRODUCTION

In every engineering applications, the essential requirement of produced products is wear resistance,especially with automotive and aircraft components.This process of enhancement of wear properties can be achieved through blending of polymers. The literatures shows that the polymer nanocomposites can provide high mechanical and tribological performance[1].

Polypropylene is one of the fastest growing classes of thermoplastics. The main attraction of polypropylene (PP) is its high performance compared to its cost ratio. Polypropylene can be easily modified to achieve enhanced properties To improve the mechanical properties of polypropylene using various kinds of inorganic fillers is used[2-5]. The use of inorganic fillers is a useful tool for improving, mechanical and tribological properties, chemical resistance, dimension stability[6-8].

Polymer-clay nanocomposites (PCN) is an area of research in which polymer is used as a matrix material and nano clays as the reinforcement particle. Clays, especially montmorillonite (MMT) minerals serve as good nanoclay fillers having proven dispersability in the organic matrix.The addition of small amount of clay (3-5 wt.%) in organic polymer matrix causes improved mechanical, thermal and barrier properties[9,10].

Polymer nano composites have improved mechanical properties, such as stiffness, heat distortion temperature (HDT), dimensional stabilities and enhanced barrier to gas permeation[11].

Finally, the fact that clay/polymer nanocomposites shows greatly enhanced properties at very low filler content. These composites can also produced simple processes such as melt intercalation, melt extrusion or injection molding, which paves new way for plastics and composites[12].

In the present study wear characteristics of melt blending of PP, PP-g-MAH (10 wt %) and the nanoclays (Na^+-MMT) of 1, 3, 5 and 7 wt % were studied with the help of Pin-on-disc wear testing machine.

EXPERIMENTAL

The polypropylene (H110MA) with density of 0.910 g/cc and MFI of 11 g/10 min (measured at 230 ºC under 2.16 kg load), obtained from Reliance Ltd., India was used as the base matrix for the present study and clay *i.e.*, Na^+-MMT (unmodified having CEC 92.6 meq/100 g clay), were obtained from Southern Clay Products Inc., USA used as additive.

Preparation of nanocomposites: Melt blending of polypropylene, PP-g-MAH (10 wt %) and the nanoclays (Na^+-MMT) of 1, 3, 5 and 7 wt % was carried out in an intermeshing counter rotating twin screw extruder (ctw-100, Haake-Germany) having barrel length of 300 mm and angle of entry 90º. Prior to extrusion, the matrix polymer and the nanoclay

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were dehumidified in a vacuum oven at 60 ºC for a period of 6 h. PP was fed at the rate of 5 kg/h and the nanoclay was subsequently introduced at the melting zone. The process was carried out at a screw speed of 150 rpm and a temperature difference of 160, 170 and 180 ºC between feed zones to die zone, followed by granulation in a pelletizer (Fission, Germany) and drying.

Preparation of test samples: The test samples of 10 mm diameter and 20 mm length cylindrical pins are prepared by using a simple die and plunger system with an electrical heating arrangement. The predetermined weighed amount of blend is fed into the die. Die is heated up to 180 ºC and the punch is pressed into the die. Die is cooled in water at 20 ºC. After the solidification of polymer blend, sample is taken out from the die for further test. The test samples prepared using die plunger system is shown in Fig. 1.

Fig. 1. Typical prepared samples

Sliding wear test: Wear tests in dry sliding condition are conducted on a pin-on-disc friction and wear-testing machine Model TR-20, manufactured by Magnum Engineers, Bangalore. India is presented in Fig. 2. The cylindrical pin specimens prepared using simple die plunger arrangement are tested against EN-32 steel of diameter 165 mm, thickness 8 mm, surface roughness 0.84 µm hardness 62HRC. The tests are conducted at varying loads ranging from 10-50 N and sliding speeds ranging from 1-5 m/s. The specific wear rates are calculated from the weight loss measurements before and after wear test. Sliding wear data reported here is the average of at least 3 runs. Before the start of test maximum contact between pin and disc has been ensured. The steel disc has been polished at the end of each test. The process is repeated until the visually observed contact area was more than 50 % of the cross-section of the pin. The friction coefficient is calculated using the following equation:

$$\mu = \frac{F_p d_p}{F_N d_N}$$

where, μ is the friction coefficient, F_p is the rate of angular friction force, F_N is the applied normal load, d_p is distance between the center to the pin and d_N is distance the center to the normal force. The coefficient of friction is directly measured using software supplied along with the machine.

The schematic arrangement of the pin-on-disc friction and wear testing machine (the pictorial view of the pin-on-disc machine is presented in Fig. 2.

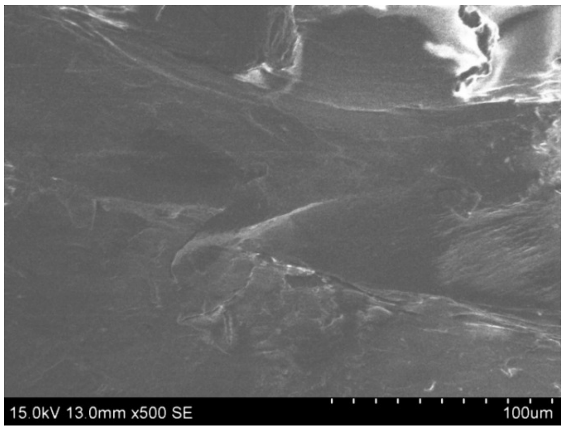
RESULTS AND DISCUSSION

The composition of the blends are given in Table-1. The fracture surface of the sample after the test was then investigated morphologically using by SEM, images of 0, 1, 3, 5 and 7 % MMT blends are shown in the above figure. In Fig. 3(a) shows image of neat polypropylene no inclusions were observed. Fig. 3(b) shows MMTs were dispersed in to the PP matrix in form of large and small aggregates. It is randomly dispersed in matrix. Nanoclay particles are dispersed separate particles also.Fig. 3(c) shows persistent slip bands of PP/MMT-97/03 composition and subsequent fracture as a result of repeated sliding after a large number of abrasion cycles.

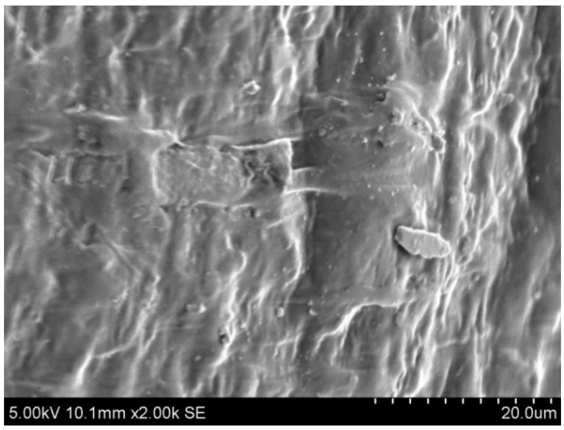
Fig. 2. Pin-on-disc friction and wear-testing machine

TABLE-1
COMPOSITION OF BLENDS

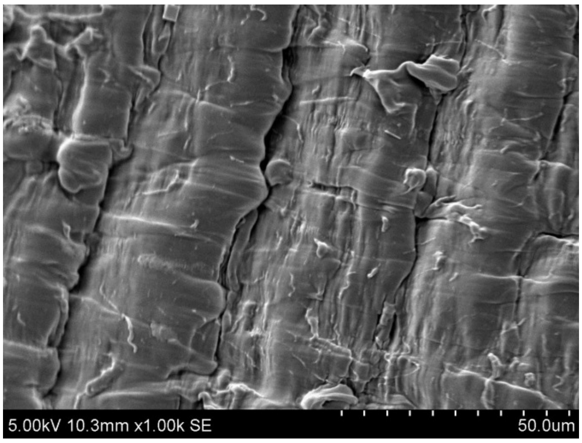
S. No	PP	Weight % of nano clay
1	100	0
2	99	1
3	97	3
4	95	5
5	93	7



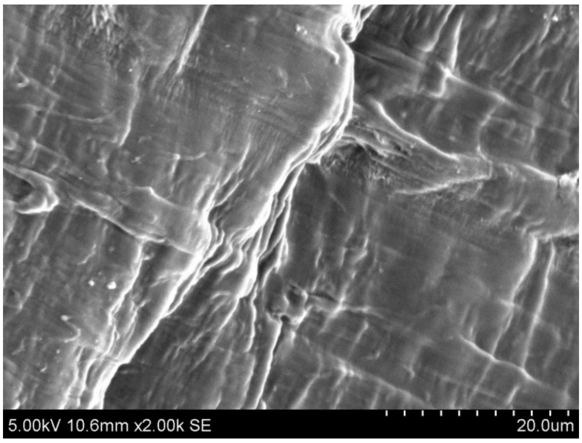
(a) PP/MMT-100/00



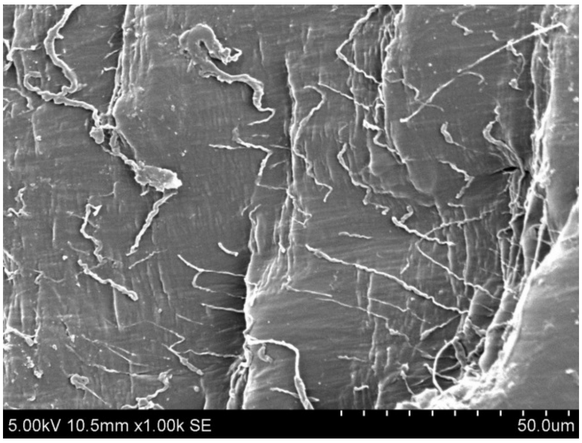
(b) PP/MMT-99/01



(c) PP/MMT-97/03



(d) PP/MMT-95/05



(e) PP/MMT-93/07

Fig. 3. SEM images showing the distribution of MMT in PP matrix

In Fig. 3(d-e) tiny white lines are seen which shows cleavage surface of broken nanoclay. It is concluded that the introduced nano clay aggregation creates resistance to wear in the polypropylene matrix.Therefore, the nanoclay introduced inside the polypropylene forms mesh like structure, When the weight percentage of nanoclay inside the polypropylene samples increased, as if the number of grid lines of the mesh increased, the mobility of polymer chains were restricted there by reducing the wear rate. Similar view has been expressed by Ho *et al.*[13] for epoxy -nanoclay composites.

Fig. 4 shows the addition of MMT in PP improves wear resistance of PP matrix. MMT is known for good wear resistance[14]. It is a plot of wear rate in terms of weight loss *vs.* appied load for PP and their blends of different compositions at 1 m/s sliding speed.In general an increased applied pressure is associated with increased wear rate of samples. PP shows maximum wear loss as compared to their blends. From the graph we can learn that wear rate decreases for the same applied pressure for PP/CNT blends. Minimum wear has been observed in PP/MMT-93/7 blend.

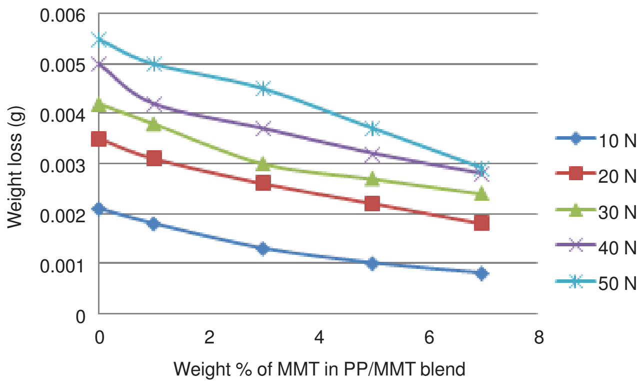


Fig. 4. Plots between wear rate in terms of weight loss and applied load for PP and PP/MMT blend system at 1 m/s sliding speed

Fig. 5 shows a plot between the wear rate and sliding speed for PP and its blends at 10 N applied load. The wear rate increases with increase in the sliding speed. From the figure we can learn that pure PP shows maximum weight loss compared to its blends. The increase in sliding speed leads to increase in temperature. strength of polymer decreases and young's modulus with increase in temperature[14].

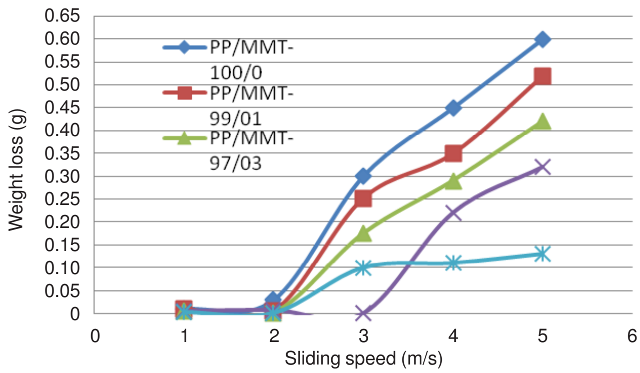


Fig. 5. Plots between weight loss and sliding speed for PP blends at constant applied load of 10 N

Both the yield strength and the tensile modulus increased with the clay content. Polymer chains are restricted in mobility contributes to the improvement of the tensile modulus in a polymer-clay hybrid. Increasing the clay content will greatly constrain the polymer chains' mobility so that the modulus is improved[15].

The effect of clay reinforcement on coefficient of friction during sliding over the abrasive paper at load of 30 N with change in sliding time shown in Fig. 6. This shows there is a sharp increase in co efficient of friction up to certain stage then starts declining slighty. It has been observed that the coefficient of friction reduces as the percentage of MMT in the PP matrix. The nanolevel reinforcement is effective in reducing the coefficient of friction. It is also noted that increase in load causes a reduction of coefficient of friction due to the increased removal of abrasive medium and surface softening due to frictional heating at the interface[16]. As decrease in ductility of the polymer due to clay addition imparts brittleness material gets easily removed without much strain leading to a decrease in the coefficient of friction.

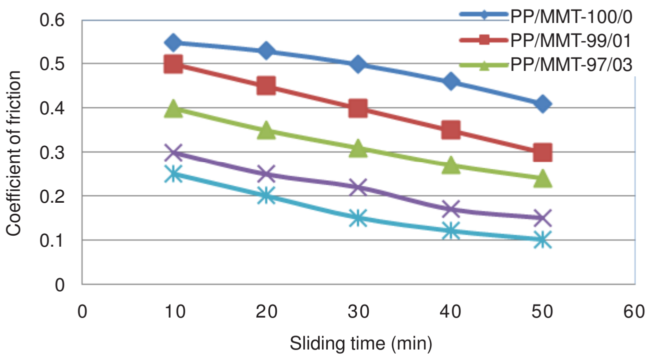


Fig. 6. Plots between the coefficient of friction (μ) and sliding time for PP and PP/MMT blend system at constant applied load 30 N and 1 m/s sliding speed

Conclusion

The addition nano clay polypropylene matrix using melt blend method clay disperssion in matrix was studied. Wear tests micro structural investigations were carried out, it was found that 7 % of MMT gave highest wear resistance compared to 1, 3 and 5 % compositions. Tests were conducted in various sliding speed, applied load and blend composition. For finding the optimal percentage content with respect to wear resistance further research is required.

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