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PROCESSING AND TRIBO BEHAVIOUR OF NYLON CLAY NANOCOMPOSITES UNDER ABRASIVE WEAR MODE

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ABSTRACT

The abrasive wear resistance and wear mechanism of polymer clay nanocomposites was reported. The Nylon clay nanocomposites used in the study were prepared by melt intercalation technique. Abrasive wear resistance was studied by using the pin-on-disk tribometer against the SiC abrasive paper. Presence of clay in nanosize reduces the ductility and reduces the abrasive wear resistance.

Keywords: Polymer clay nanocompsoties, Nylon, abrasive wear, mechanisms

1. INTRODUCTION

Polymer based materials are emerging as a good replacement for metals especially in tribological applications due to its unique advantages such as light weight, low coefficient of friction, wear resistance and self lubrication capacity [1]. Polymers are reinforced with fibres and fillers to improve the mechanical and triboligical properties and to achieve better strength-to-weight ratio. In applications like gears and bearings sliding wear resistance plays a significant role on the part performance. Polymer and its composites are also being used in vanes and gear pumps handling industrial fluids, sewage and abrasive-contaminated water, roll neck bearings in steel mills subjected to heat, shock loading; chute liners abraded by coke, coal and mineral ores; bushes and seals in agricultural and mining equipment, where abrasive wear resistance decides the part life [2]. Hence a full understanding of the effects of all system variables on the abrasive wear behaviour is necessary.

Abrasive wear behaviour of conventional polymer composites is reported in literature [3-6]. The effect of reinforcement on the abrasive wear resistance shows both detrimental and beneficial effects depending upon the reinforcement and the matrix. A decrease in the specific wear rate in abrasive wear mode by reinforcing polyetherimide (PEI) and polyethersulphone (PES) with glass fibres was reported [3,4]. The abrasive wear resistance of ultrahigh molecular weight polyethylene (UHMWPE) is improved significantly after reinforcement with quartz powder [5]. Aramid fabric reinforced polyetherimide [PEI] was reported to be more wear resistant than unreinforced PEI [6].

Polymer Nanocomposites are a new class of materials that are prepared by reinforcing at nanometer level. The strength and modulus of these polymer nanocomposites are superior compared with unreinforced polymers [7]. Nanolevel reinforcement also affects the tribological properties. Polymer Nanocomposites exhibits good wear resistance in sliding wear mode [8,9,10]. Very little data is available on the abrasive wear behaviour of nanocomposites. This paper aims to investigate the friction and wear characteristics of Nylon clay nanocomposites under abrasive wear conditions.

2. MATERIALS AND PROCESSING

Layered polysilicate clays like montmorillonite, hectorite, and saponite are the few potential precursors used for producing nanolevel dispersion [7]. These clays have silicate layers held together by weak bonds. The organically modified clays or organoclays helps in better intercalation and exfoliation. Commercial grade Nylon 6 is used in preparing the nanocomposites. The organoclay used was montmorillonite modified by 2 methyl, 2 hydrogenated tallow quaternary ammonium chloride (supplied by Elementis Specialties, USA). The 5% organoclay (by weight) was mixed with Nylon 6 pellets thoroughly using a screw mixer and fed into the twin-screw extruder. The extrudate was cooled by passing through a water bath. The extrudate are made into pellets by chopping in a chopper. The mechanical properties of the test materials are listed in Table 1. The X ray diffraction analyses were conducted on the molded specimens to find out the dispersion of clay in nanocomposite.

3. ABRASIVE WEAR TEST

Abrasive wear tests were conducted on a pin-on-disk machine modified to test under abrasive mode. The SiC waterproof emery paper (Grade 80) was affixed on the disk. Cylindrical specimens of dimensions 8 mm in diameter and 20 mm in length were injection moulded. The friction force was measured by using a force transducer fixed on the loading lever arm. A non-contact laser displacement transducer was used to measure the linear wear during the tests. Friction force and linear wear were measured continuously and data were stored using a personal computer based data acquisition system. Friction and wear tests were conducted at normal loads 5 and 10 N. Tests were performed at a constant sliding velocity of 0.2 m/s. Tests were conducted under laboratory conditions (32°C ± 3°C, RH 57% ± 5%).

The sliding surfaces of the pins were well cleaned before testing. The initial mass of pins was measured using an electronic balance of 0.1 mg accuracy and the dimensions of pins were measured using a digital micrometer of accuracy 1 mm. Tests were run up to a sliding distance of 180 m. After the test the pin was cleaned and the specimen mass and surface roughness were measured. Three tests were conducted under each test condition and the average values of measured friction force, temperature, linear wear and mass loss were used for further analysis. The specific wear rate K (g/m), is the ratio of the mass loss to the sliding distance. The worn-out surfaces were observed using optical microscope.

4. RESULTS AND DISCUSSION

Figure 1 shows the X-ray diffraction patterns for organoclay and Nylon 6 nanocomposite. Organoclay shows a diffraction peak at 7.2° corresponding to the gallery spacing between the clay platelets. During melt processing the polymer molecule intercalates into the galleries of the clay and exfoliates the layers. Hence the gallery distance is not detected in the X-ray diffraction patterns of Nylon 6 nanocomposite.

The effect of clay reinforcement on coefficient of friction during sliding over the abrasive paper at normal loads ranging from 5 to 10 N respectively is shown in Figs 2 and 3. Nylon nanocomposite exhibits lowest coefficient of friction at both normal loads investigated. 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 [11]. 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

The effect of sliding distance at the normal load of 5 N on linear wear during tests conducted is shown in Fig 4. The nanolevel reinforcement is detrimental to abrasive wear resistance of the composites. The 5% addition of clay drastically increases the abrasive wear by four times compared with pristine nylon for sliding on the abrasive paper for a distance of 180 m. The ductility of Nylon reduces with the addition of clay [Table 1]. With 5% clay addition the elongation at break falls from 384% to 95%. The abrasive wear performance greatly depends on the ductility or the elongation at break of the material [4, 12, 13]. Higher the ductility higher is the wear resistance. Hence the abrasive resistance decreases with increasing clay content. Fig 5 represents the linear wear loss with sliding distance at a normal load of 10 N. Similar behaviour was observed at a higher load of 10 N.

During sliding on the abrasive paper, the linear wear rate initially was high and later it stabilizes (Figs 4 and 5). This behaviour is due the clogging of the wear debris on the emery paper. The entrapment of the wear debris on the abrasive paper prevents the direct contact of the grit and the polymer asperity and reduces the rate of linear wear.

An increase in load causes a decrease in the wear of Nanocomposites. Similar results of decreasing wear with increasing load of fibre reinforced polymers are reported [3, 4, 14]. This behaviour is due to the formation of ridges on the surface of the polymer during sliding on an abrasive medium [14]. The material from the grooves is not removed but rather displaced towards the sides to form the ridges. Hence quantification of wear losses either by dimension loss or mass loss does not give the right picture of the actual loss. Hence there seems to be a reduction in the wear loss with increasing load. Fig 6 shows the effect of load on the wear rate, which also reflects the same discussion, mentioned above.

Wear morphology of the Nylon and nanocomposites at the normal load 5 N is shown in Fig 7. Ploughing action of the abrasive grits is predominant in both the materials. Fig 7a shows the wear morphology of Nylon 6 where the abrasive action is not severe due to high ductility of Nylon. Ridge formation is clearly evident on Nylon with 5% (Fig 7b) clay causing a reduction in the wear rate at higher loads.

5. CONCLUSIONS

1. Nanolevel reinforcement is effective in reducing the coefficient of friction. Nylon nanocomposite exhibited least coefficient of friction than pristine Nylon
2. Nanolevel reinforcement has detrimental effect on abrasive wear at 5 N and 10 N load due to decrease in the elongation to break.
3. For Nanocomposites, increase in the load causes a decrease in wear, due to ridge formation
4. Wear morphologies show that plowing action is predominating in both materials.

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TABLES

Table 1 Mechanical Properties of Nylon Nanocomposites

Materials	Nylon 6	Nylon + 5% Clay
Tensile Strength (MPa)	44.6	50.8
Modulus (MPa)	145	315
Elongation at Break	384%	95%

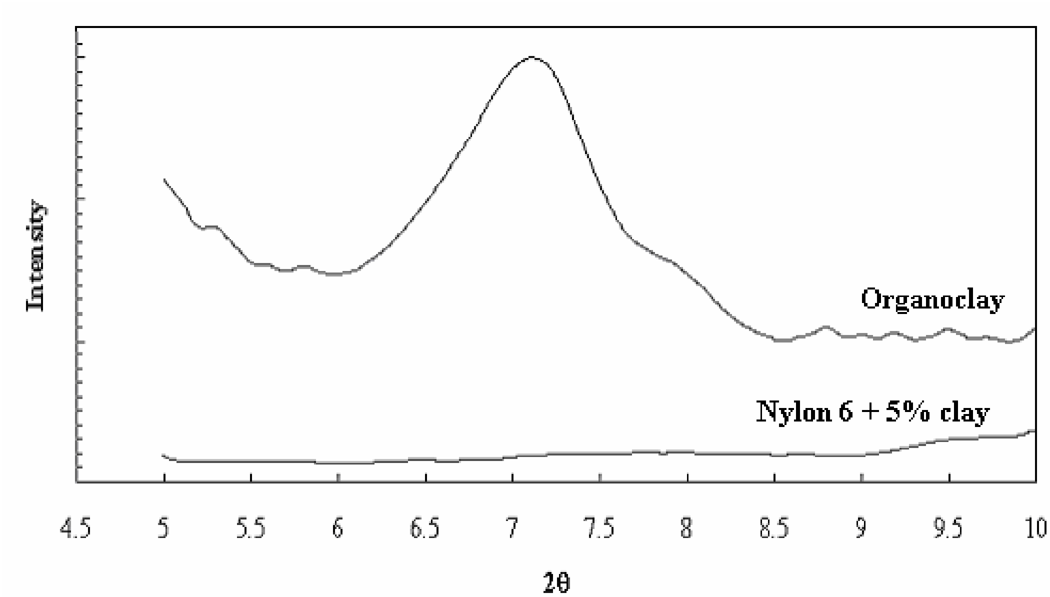

Fig 1 X-ray diffraction patterns of organoclay and Nylon 6 nanocomposite

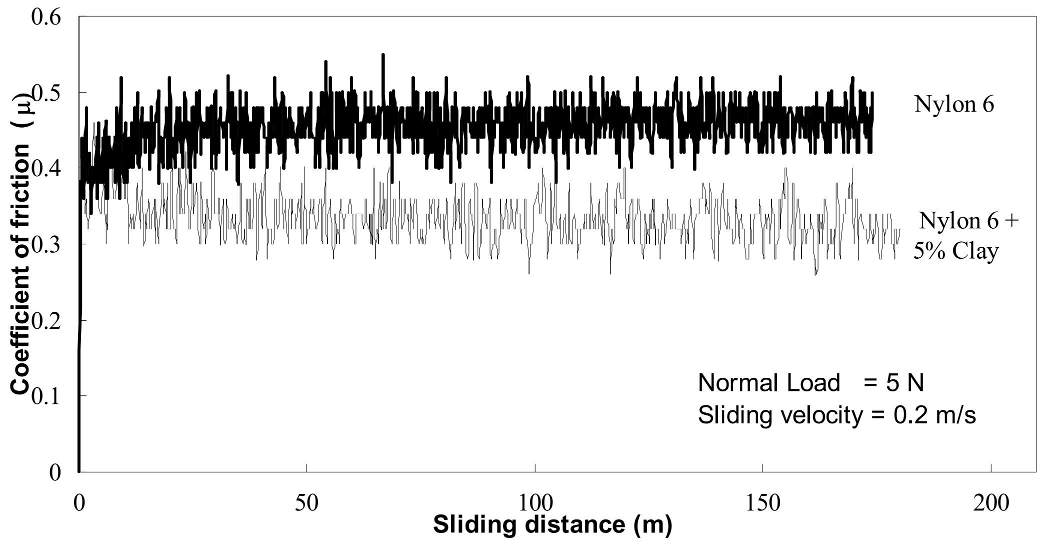

Fig 2 Effect of sliding distance on coefficient of friction at normal load of 5N and sliding speed of 0.2m/s under abrasive conditions

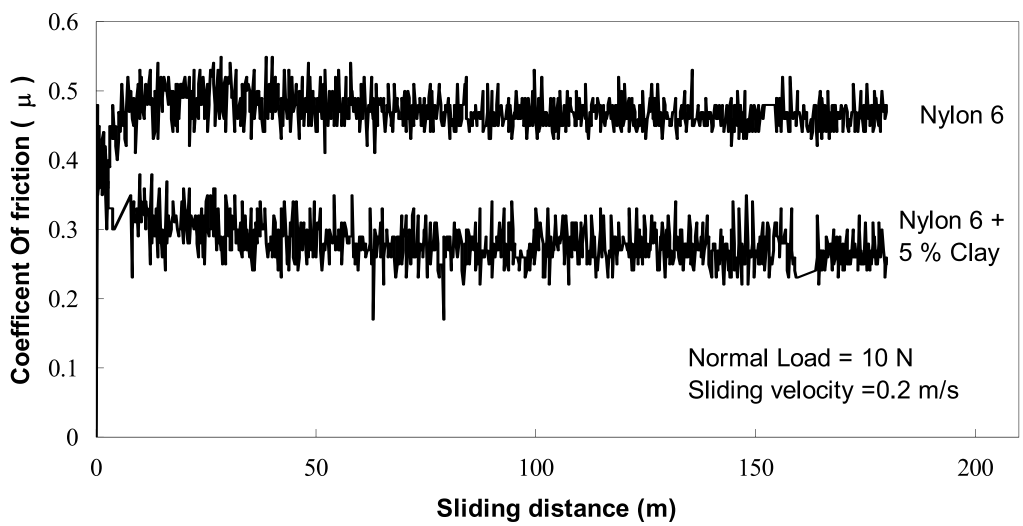

Fig 3 Effect of sliding distance on coefficient of friction at normal load of 10 N and sliding speed of 0.2m/s under abrasive conditions

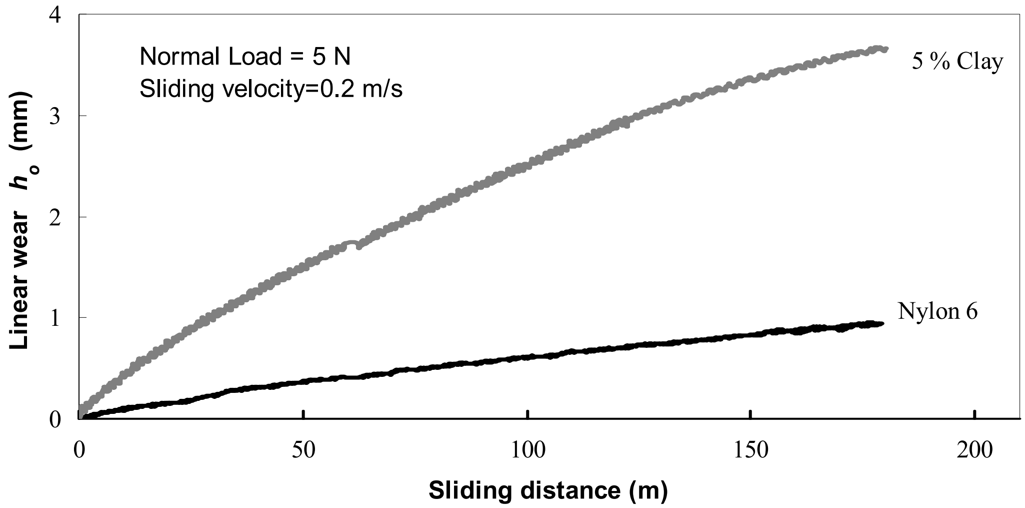

Fig 4 Effect of sliding distance on linear wear at normal load of 5 N and sliding speed of 0.2m/s

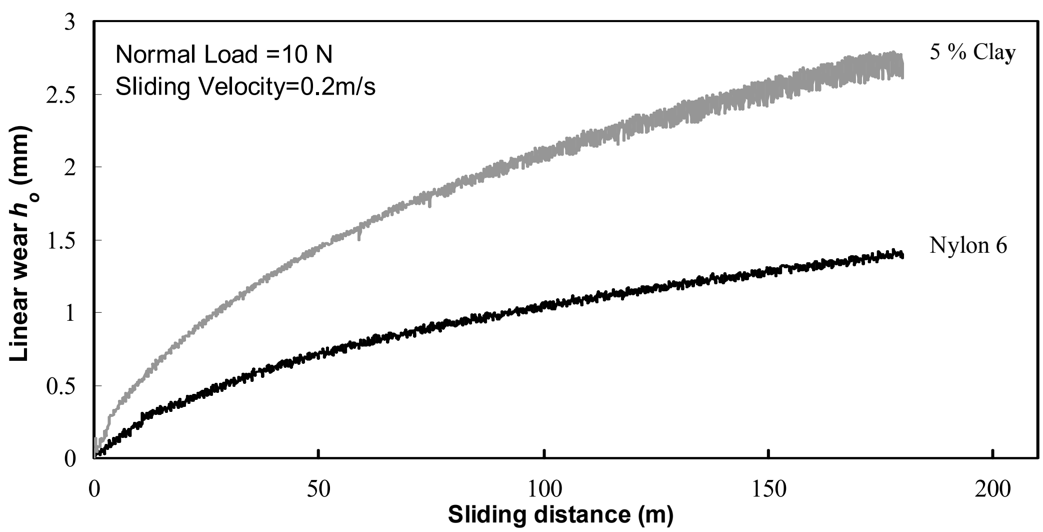

Fig 5 Effect of sliding distance on linear wear at normal load of 10 N and sliding speed of 0.2m/s

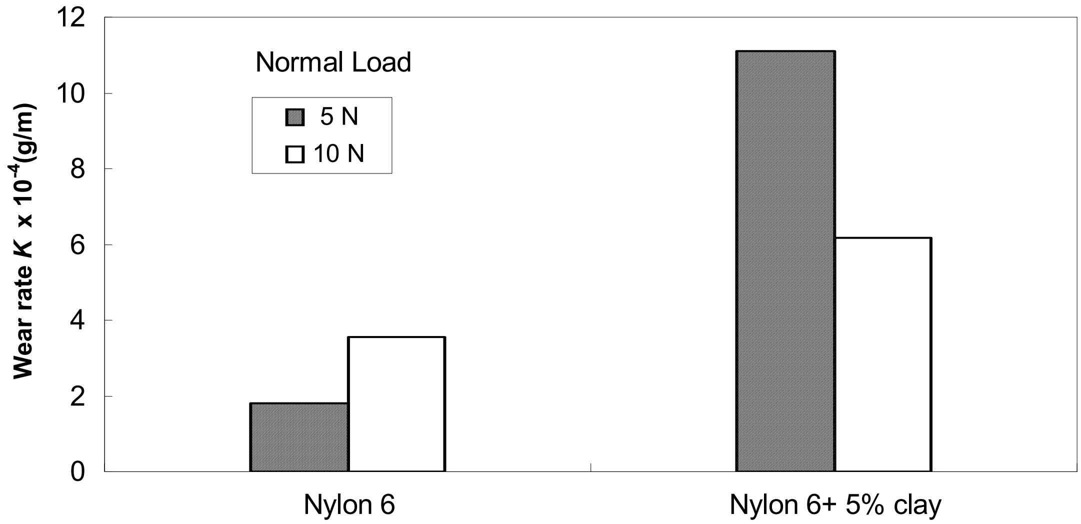

Fig 6 Effect of clay reinforcement on wear rate

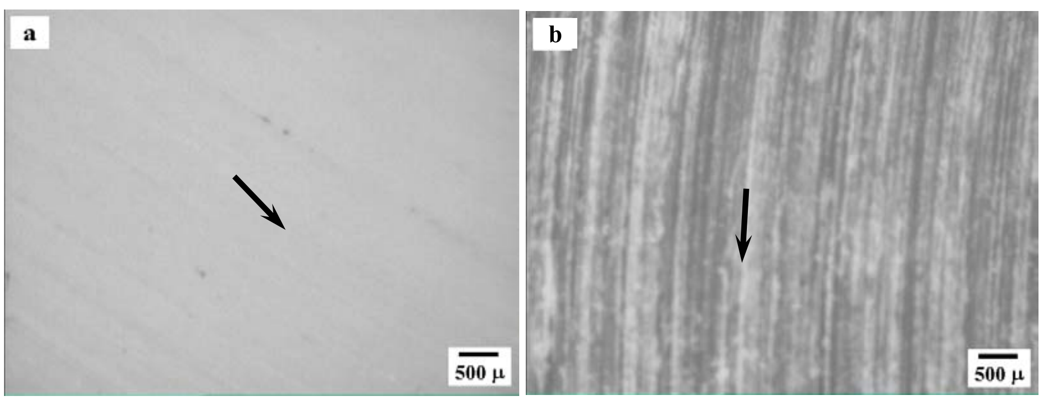

Fig 7 Abrasive wear morphology of a) Nylon 6 and b) Nylon + 1% clay at the normal load of 5 N (arrow indicates the sliding direction)