

# Tribological behaviours of nanoclay filled polyamide-6/polypropylene/compatibilizer composite against stainless steel counter-face

## Abstract

In this experimental study, tribological behaviors of nanoclay filled polyamide-6/Polypropylene (PA6/PP) polymer blend with styrene-ethylene/butylene-styrene (SEBS-g-MA) compatibilizer were studied. Tribological studies were carried out using a pin-on-disc wear test machine under dry sliding conditions. Tribological tests were run at the applied load of 25, 50, 100, and 150N value and the sliding speed of 0.5m/s. The results show that the addition of compatibilizer into the polyamide-6/polypropylene blend resulted to enhancement in coefficient of friction and specific wear rate values while montmorillonite 5wt.% nanoclay addition into the PA6/PP-5% SEBS-g-MA blend resulted to an increment in specific wear rate value but decrease in coefficient of friction. Moreover, an optical microscope was used to investigate microstructural properties of polyamide-6/PP/SEBS-g-MA polymer blend and composite.

**Keywords:** polyamide, polypropylene, compatibilizer, nanoclay, wear

Volume 2 Issue 1 - 2018

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**Received:** October 17, 2017 | **Published:** January 31, 2018

**Abbreviations:** PA6/PP, polyamide-6/polypropylene; SEBS-g-MA, styrene-ethylene/butylene-styrene; PP, polypropylene

## Introduction

Polyamide polymers have moderate mechanical properties, excellent wear resistant properties, and solvents. However, polyamides have some disadvantages such as notch sensitivity and high water absorption. Generally, polyamides are ductile in the un notched state but they show brittle behavior in the state of notched impact. Some disadvantages of polyamides can be improved by some fillers and additives. Maleic anhydride functionalized styrene-ethylene-butylene-styrene and ethylene-propylene elastomer copolymers were used to improve notched impact strength values of the polyamide polymers composites.

Polypropylene (PP) polymer is an attractive material with respect to easy processability, cheap, lightweight and resistance to most of chemicals. However, PP has some disadvantages such as lower strength and impact strength especially at lower than-10°C temperatures. Some elastomers are added to polypropylene polymer to reduce its stiffness, hardness, and strength. Moreover, some macro and nano size rigid inorganic mineral fillers such as talc,<sup>1-4</sup> calcium carbonate,<sup>5-7</sup> glass bead,<sup>8-9</sup> and clay<sup>10-11</sup> were added to improve the mechanical properties of polypropylene polymer.

PP/PA6 blending has been attempted to achieve important improvement in mechanical properties, where PP consumes good processability while PA6 contributes mechanical and thermal properties.<sup>12</sup> Furthermore, Nano composites based on PA6/PP blends has been extensively studied.<sup>13</sup> Denac et al.<sup>14</sup> studied PP/Talc/SEBS (SEBS-g-MA) composites structure and mechanical properties. Kusmono et al.<sup>15</sup> reported compatibilizing effect of SEBS-g-MA on the mechanical properties of different types of OMMT filled polyamide 6/polypropylene composites. They concluded that the

addition of SEBS-g-MA into the nano-composites enhanced strength and impact strength but slightly reduced stiffness of the material.

In order to study the influence of SEBS-g-MA and nano-clay filler on the tribological properties of PA6/PP polymer blend. PA6/PP-5% SEBS-g-MA blend and PA6/PP-5% SEBS-g-MA-5% nanoclay composite were produced by a twin screw extruder. Friction and wear tests against AISI 440C stainless steel disc were performed on a pin-on-disc arrangement at dry sliding conditions. Influence of SEBS-g-MA compatibilizer and nanoclay filler on the tribological performance was evaluated. In addition, the effect of applied load and sliding speed on the tribological properties were also investigated for PA6/PP polymer blend, PA6/PP-5%SEBS-g-MA blend and PA6/PP-5% SEBS-g-MA-5% nano clay composite materials.

## Experimental

### Materials

The polyamide 6 thermoplastic polymer used in this study is an industrial product (Akulon F 223 D) from DSM, Turkey. Polypropylene polymer is also industrial grade product (Novolen 1100N) supplied by BASF, Germany. Styrene-ethylene/butylene-styrene triblock copolymer grafted with 1.84% maleic anhydride (trade name: Kraton FG1901X) was supplied by Shell Chemical Company, USA. Nanoclay material, Nanomer I 30TC, was supplied by Nanocor Inc. USA.

### Preparation of PA6/PP/SEBS-g-MA/nanoclay composite

For material compositions used in this study, see Table1. Prior to melt processing steps, polyamide 6, polypropylene and SEBS-g-MA polymers were dried in a conventional oven at 80°C for 4 hours. PA6/PP and PA6/PP-SEBS-g-MA polymer blends and nanoclay filled PA6/PP-SEBS-g-MA composite were prepared by melt compounding

using a twin screw extruder (Werner & Pfleider ZSK25). The PA6/PP blend composition was kept constant (PA6/PP ratio by weight=70/30), 5wt.% SEBS-g-MA and 5wt.% nano clay. Compounding was melt-mixed in a twin screw extruder at temperature ranged from 220 to 245°C. The extrudates were cooled in water pool and then pelletized

with a pelletizer. Prior to injection molding, extrudates dried in an oven at 80°C for 4 hours. To evaluate tribological performance of the materials used, the test samples were prepared by injection molded using an injection molding machine (ERAT, Istanbul, Turkey). Injection molding parameters are shown, see Table 2.

**Table 1** Compositions (wt.%) of materials used in the study

Polymer blends	Polyamide-6 (wt.%)	Polypropylene (wt.%)	SEBS-g-MA (wt.%)	Nanomer (I 30TC) (wt.%)
PA6/PP	70	30	0	0
PA6/PP-5% SEBS-g-MA	70	30	5	0
PA6/PP-5% SEBS-g-MA-5%nanoclay	70	30	5	5

**Table 2** Injection molding process parameters for materials used in the study

Injection molding process parameters	PA6/PP	PA6/PP-5% SEBS-g-MA	PA6/PP-5% SEBS-g-MA-5% nanoclay
Feeding zone temperature (°C)	220	220	225
Precompression zone temperature (°C)	230	230	235
Compression zone temperature (°C)	245	245	250
Mold temperature (°C)	50	50	50
Injection pressure (MPa)	100	100	100
Injection speed (mm/s)	5.8	5.8	5.8
Injection time (s)	6	6	6

Tribological tests were performed using a pin-on-disc wear test machine. The cylindrical wear pin material was 6 mm in diameter and 50mm in length. For wear test, AISI 440C stainless steel disc was used as a counter-face material. During wear test, friction force was measured by a load cell. Force readings were taken as the average of 1500 readings every 60s for a period of the testing time. For this purpose, a microprocessor controlled data acquisition system was used. For tribological test, coefficient of friction ( $\mu$ ) and specific wear rate values were evaluated. Coefficient of friction values were calculated as follows;

$$\mu = F_f / F_N$$

Where  $F_f$  is the friction force and  $F_N$  is the applied load on the sample. Specific wear rate is defined as the wear volume normalized by the normal load and sliding distance. The amount of wear was measured by weighting the pin before and after the tests an accuracy of  $1 \times 10^{-4}$ g in a precision balance. The mass loss (m) was measured after each set of run and volume loss (V);  $V=m/\rho$  was found by using density ( $\rho$ ) of the specimen. The following relationship was used to estimate the specific wear rate ( $m^3/Nm$ );

$$W_{sp} = V / F_N L$$

Where L is the sliding distance. Sliding wear data reported here is the average of at least three runs. Before and after each test, the samples were ultrasonically cleaned and dried in a warm air. Wear tests were carried out at room temperature ( $23^\circ\text{C} \pm 2$  and  $51 \pm 3\%$  humidity), applied load values of 25, 50, 100 and 150N and sliding speed of 0.5m/s.

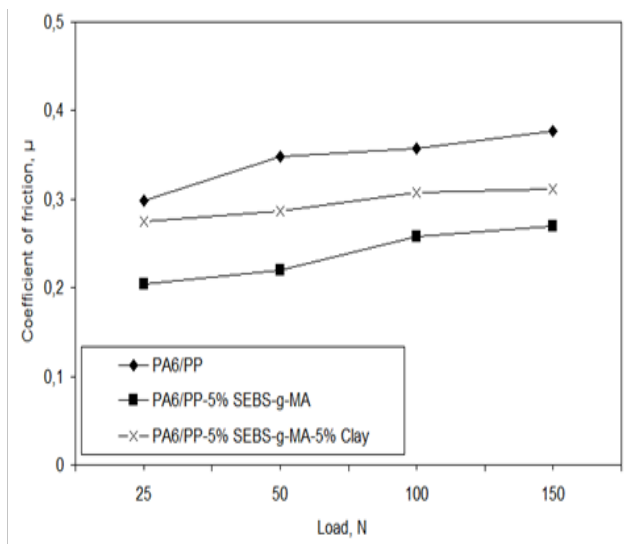
## Results and discussion

Figure 1 presents the variation of coefficient of friction with applied load for PA6/PP blend, PA6/PP-5%SEBS-g-MA blend and

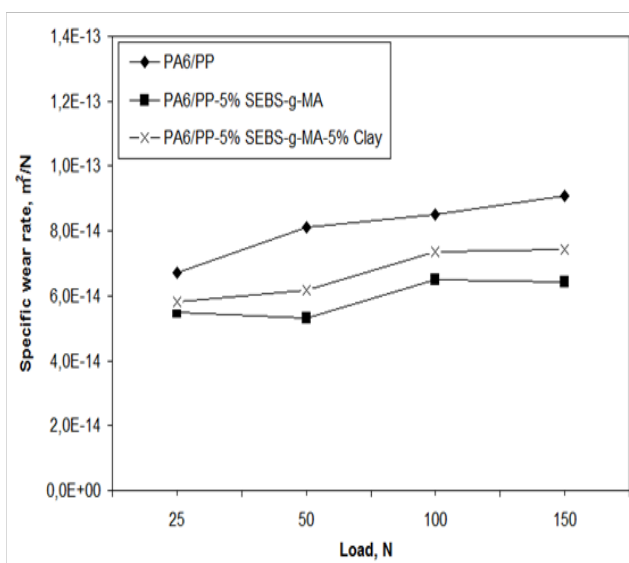
PA6/PP-5%SEBS-g-MA-5% nanoclay composite at the sliding speed of 0.5m/s. It is clear from this figure that the coefficient of friction increased with the increment of applied load values. Among the materials used, the lowest coefficient of friction values are 0.20 for PA6/PP-5%SEBS-g-MA blend followed by 0.27 for PA6/PP-5%SEBS-g-MA-5% nanoclay composite and then followed by about 0.30 for PA6/PP blend under the load of 25N. In comparison with PA6/PP blend, the decrease in COF is about 33% for PA6/PP-5%SEBS-g-MA blend and 10%PA6/PP-5%SEBS-g-MA-5% nanoclay composite. The highest coefficient of friction values are 0.38 for PA6/PP blend followed by 0.31 for PA6/PP-5%SEBS-g-MA-5%nanoclay composite and then followed by about 0.27 for PA6/PP-5%SEBS-g-MA blend under the load of 150N. The decrease in coefficient of friction is about 18% and 29% for PA6/PP-5%SEBS-g-MA-5% nanoclay composite and PA6/PP-5%SEBS-g-MA blend, respectively when comparing with PA6/PP blend. 0.5m/s sliding speeds, the COF values increased with the increase in applied load. This could be explained by rising of surface temperature during rubbing process of all materials used and counter-face steel material. The increase in surface temperature leads to softening of polymer materials used and increasing in COF values.

Figure 2 shows the variation of specific wear rate with applied load for PA6/PP blend, PA6/PP-5%SEBS-g-MA blend and PA6/PP-5%SEBS-g-MA-5% nanoclay composite at the sliding speeds of 0.5m/s. This figure shows that, the specific wear rate values increase with the increase in applied load from 25N to 150N. The highest specific wear rate values are for PA6/PP blend with a value of  $9.1 \times 10^{-14} \text{m}^2/\text{N}$  at 0.5m/s sliding speed and 150N applied load followed by  $7.4 \times 10^{-14} \text{m}^2/\text{N}$  for PA6/PP-5%SEBS-g-MA-5%nanoclay composite. And then the specific wear rate are  $6.5 \times 10^{-14} \text{m}^2/\text{N}$  for PA6/PP-5%SEBS-g-MA blend at 0.5m/s sliding speed and 100N applied load. Furthermore, the results show that the specific wear rate decrease with the addition of SEBS-g-MA and nanoclay filler into the PA6/PP blend. When it is compared the PA6/PP blend, the specific wear rate decrease

about 19% for PA6/PP-5%SEBS-g-MA-5%nanoclay composite and 29% for PA6/PP-5%SEBS-g-MA blend. The lowest specific wear rate values are  $5.3 \times 10^{-14} \text{m}^2/\text{N}$  for PA6/PP-5%SEBS-g-MA blend at the sliding speed of 0.5m/s and 50N applied load followed by  $5.8 \times 10^{-14} \text{m}^2/\text{N}$  for PA6/PP-5%SEBS-g-MA-5% nanoclay composite and followed by  $6.7 \times 10^{-14} \text{m}^2/\text{N}$  for PA6/PP-5%SEBS-g-MA blend at 25N and 0.5m/s sliding speed.



**Figure 1** The relationship between coefficient of friction and applied load for PA6/PP blend and PA6/PP-5%SEBS-g-MA blend and PA6/PP-5%SEBS-g-MA-5%nanoclay composite (sliding speed: 0.5m/s).



**Figure 2** The relationship between specific wear rate and applied load for PA6/PP blend and PA6/PP-5%SEBS-g-MA blend and PA6/PP-5%SEBS-g-MA-5%nanoclay composite (sliding speed: 0.5m/s).

## Conclusion

From the results of this study, the following conclusions are reached;

- i. The coefficient of friction value increased with the increase in applied load from 25N to 150N at sliding speed of 0.5m/s for PA6/PP blend, PA6/PP-5% SEBS-g-MA blend and PA6/PP-5%

SEBS-g-MA-5%nanoclay composite materials.

- ii. The specific wear rate values increased with the increase in applied load from 25N to 150N at the sliding speed of 0.5m/s for PA6/PP blend, PA6/PP-5% SEBS-g-MA blend and PA6/PP-5% SEBS-g-MA-5%nanoclay composite.
- iii. The addition of SEBS-g-MA compatibilizer into the PA6/PP polymer blend result to a decrease in coefficient of friction and specific wear rate values.
- iv. The addition of 5wt.% nanoclay to the PA6/PP-5% SEBS-g-MA polymer blend lead to the increase in coefficient of friction and specific wear rate values.

## Acknowledgements

The authors acknowledge University of Sakarya, Commission of Scientific Research Projects (BAPK) for providing financial assistance (Project no: 2012-09-08-002).

## Conflict of interest

The author declares no conflict of interest.

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