INVESTIGATION OF FRICTION AND WEAR BEHAVIORS FOR A SILICA/POLYPROPYLENE NANOCOMPOSITES

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Introduction

Silica/polymer composites were found posses unique physical, chemical and electromechanical properties, which have extensive application potential [1]. The addition of various nanosized fillers into polymer which may cause an improvement in the tribological feature at low filler contents due to a change of the wear mechanisms were reported by Wang and Xue [2]. In 2005, Su and coworkers [3] revealed the friction and wear behaviors of the resulting carbon fabric composites sliding against AISI-1045 steel in a pin-on-disk apparatus. Nanofillers, such as TiO_2, ZnO, SiO_2 and Si_3N_4 were reported to be effective in improving the friction and wear properties of some polymer and fabric composites [4, 5]. In order to depict synergistic structures and effects of tribological improvement, the attention in this work is focused on the fabrication, friction and wear properties of the hybrid nanocomposite with various filler contents. The wear behaviors and tribological properties were characterized o build the correlation between the nanoparticle and the friction parameters, so as to provide knowledge for an optimum material preparation for dry-sliding. A scanning electron microscope revealed that the influence of fillers on the corresponding wear mechanism can be measured by the morphology of abrasion surface.

Material and experimental processing

Commercially available colloidal silica in methanol with 12 nm particle size, provided by JJ Degussa, was used as inorganic filler. The organic polypropylene polyolefin matrix containing tetraethylene glycol diacrylate was used as the oligomer. Various amounts of colloidal silica (10 ~ 50 wt%) were added to the blends to create silica / polypropylene polyolefin hybrid samples. All test samples, with 5 mm in diameter and 0.8 mm in thickness, were affixed on the circular face of a pin with 5 mm in diameter and 10 mm in length, which will be firmly clamped on specimen holder. As given in Fig. 1, a counter-body of AISI-O1 carbon steel disk with a diameter of 50 mm initial surface roughness of

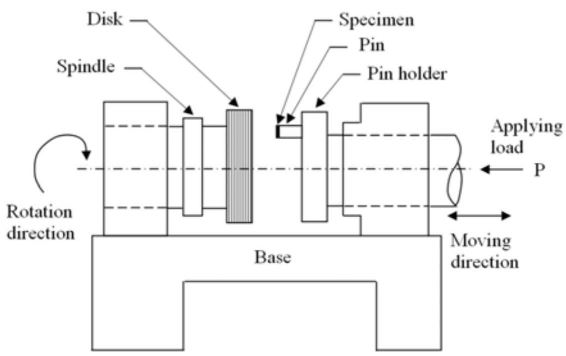

Fig.1 Schematic diagram of pin-on-disk type friction and wear tester.

R_a =0.15 μm and hardness of 65 HRC was used in the wear test. Un-lubricated sliding wear test was performed under ambient condition for 5 hours at normal loads from 100~200 N and velocity from 0.5~3.0 m/s. The wear coefficient was calculated by dividing the material loss by the applied load and sliding distance, i.e. wear rate (ω_c) = Volume of material loss (mm^3) / [Applying load (N)*Sliding distance (m)]. The morphologies of the wear trace and the interlayer bonding of the as-spun material in the nanocomposites was studied by using a Siemens D300 apparatus with a scanning rate of 0.5 °/min.

Results and discussion

Table.1 lists the adhesion strength of the silica nanocomposite containing various SiO_2 / poly ratio. It is indicated that the adhesion strength increase when the silica content increases in the SiO_2 / polyacrylate ratio ranges from 10 to 30 wt%.

Table 1
Compositions of silica / poly nanocomposites.

Sample	Silica (wt%)	TPM (wt%)	PA (wt%)	Adhesion Strength G'(MPa)
Pure PA (PPA)	0	0	100	
PS10T	9.6	7.2	83.2	88.3
PS20T	19.12	14.34	66.54	98.6
PS30T	29.14	21.86	49.0	107.4
PS40T	38.68	29.01	32.31	107.2
PS50T	48.04	36.03	15.93	106.1

To show the maximal loading ability at a fixed velocity of 2 m/s, wear coefficient as a function of normal load for PPA and silica / polypropylene polyolefin nanocomposite is given in Fig.2. All composites filled with various silica particles show better wear resistance than the pure polypropylene polyolefin. The incorporation of coupling agent (TPM) at nanocomposite containing 30 wt% of silica show the best wear-resistance among the test specimens. All the test samples have decreased wear coefficient with increasing normal load until the wear coefficient getting increased or keep nearly unchanged above 160 N of normal load. As a result, a strong tendency of the nanofiller to agglomerate can minimize the splitting of the bonded nanoparticles and decrease the wear rate. Fig. 3 shows the variation of wear coefficient with sliding velocity for PPP and its nanostructure with coupling agent. It is seen that the unfilled pure polymer matrix and those filled with various silica content nanocomposite show slightly decreased wear

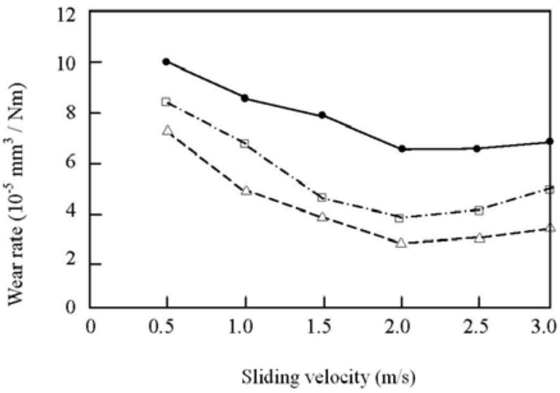

Fig. 2 Wear rate as a function of sliding velocity for pure polypropylene and silica/poly composites: (——) PPP; (– · –) PS30; (- - -) PS30T.

coefficient with increasing sliding velocity over the range of sliding velocities from 0.5 to 2 m/s. Subsequently, the wear coefficients gradually begin to rise with enhancing the sliding speed until the maximum velocity, 3 m/s. It can be seen from Fig. 4 that the worn surfaces of all specimens at different sliding velocities were covered with grooves parallel to the fretting direction. These features suggest that the hard asperities on the steel counter-face or the hard particles in between the friction interface may cause abrasive wear by the removal of small fragments of material. As can be seen from Fig. 4(a) to (c), the obvious deep grooves found at lower velocity is changing to shallower tracks accompanied by abrasive deformation at higher velocity. The adhesion strength of the hybrid specimen was determined from the recorded load-displacement curve. The adhesion strength, σ_A , was calculated as $\sigma_A = P/(L*W)$, where P is the applied force, L and W represent the length and width of the adhered area..

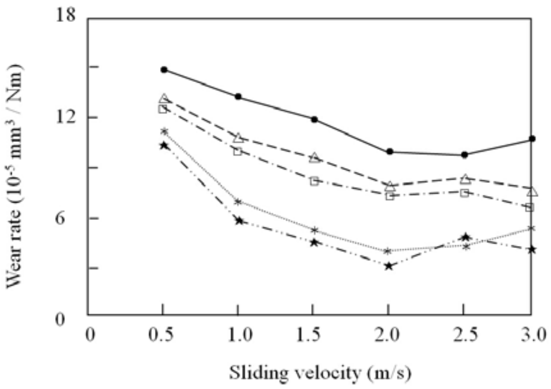

Fig. 3 Variation of wear rate with sliding velocity for PPP and silica/polypropylene polyolefin composite with various silica contents: (——) PPP; (- - -) PS10ST; (– · –) PS20T; (········) PS30T; (– · · –) PS50T.

Conclusions

The results of this study have shown that the incorporation of silica and coupling agent at optimal content result in increasing the wear resistance and friction-reducing ability of the hybrid nanocomposite. The nanocomposite filled with 30 wt% silica was found to have the lowest wear coefficient and friction coefficient. The extensive plastic deformation in the pure polypropylene polyolefin can be attributed to the formation of persistent slip bands and subsequent fracture as a result of repeated sliding after a large number of abrasion cycles. Abrasion and deformation were the dominant wear mechanism with a transition to softening effect on fretting surface at excessive high sliding velocity. The variation in the morphological features of the PPP and hybrid with silica filler are related to difference in their interfacial bonding and the nature of transfer films formed on the counterpart surface.

(a)
(b)
(c)

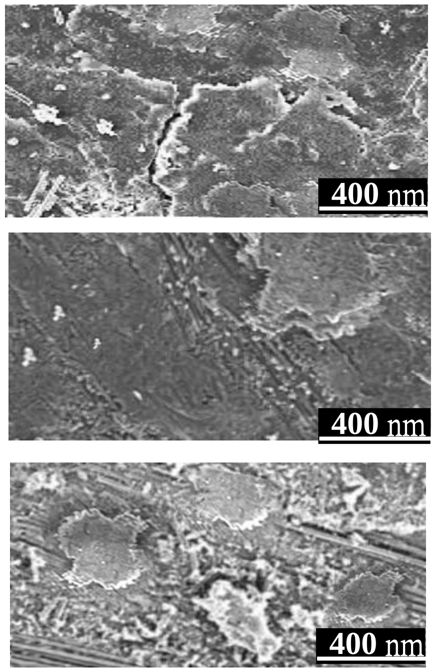

Fig.4 SEM micrograph of the worn surfaces morphological Features on PPA and its nanocomposites at high sliding speed (v = 3 m/s): (a) PS10T ; (b) PS30T ; (c) PPA.

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