1 Introduction

Two kinds of nanosilica particles, colloidal and pyrogenic ones, were employed to prepare transparent polymeric coatings. We systematically studied their erosive and abrasive wear behaviors performed at different test conditions; the worn surfaces of the nanocoatings were examined, and wear mechanisms were discussed subsequently.

2 Experimental

2.1 Coating preparation

The coating preparation was described in detail in our former work [1,2]. Briefly speaking, the colloidal nanosilica sol (‘C150’, mean particle size = 20 nm) and the pyrogenic nanosilica particles (‘R7200’, mean particle size = 12 nm) were supplied by Evonik Degussa GmbH. The pyrogenic nanosilica particles R7200 were mechanically dispersed in the TMPTA using a high-speed dissolver and a three-roll mill machine to prepare masterbatch. Then the C150 and the masterbatch were thinned down by proper amount of hexa-functional aliphatic urethane–acrylate (UA) oligomer (‘Ebecryl 1290’), TMPTA and photoinitiator to gain dispersions with varying nanoparticle contents. The dispersions were spin-coated onto polycarbonate substrates and then cured by ultraviolet rays.

2.2 Erosive test

Erosive tests were performed at room temperature by using a sand-blasting machine ST 800J (Paul Auer GmbH). Under compressed air, the erodent particles left the nozzle and struck against the coating sample. The distance between coating sample and nozzle was set to be 160 mm, and the diameter of eroded area was 20 mm. Sharp-edged and round steel erodent particles were used.

2.3 Abrasion test

The abrasive wear behavior of the coating samples was evaluated by a Taber Abraser (Taber 5155). The abrasion test typically involved a normal load of 9.8 N, a rotation speed of 60 rpm (according to ASTM D4060-95). To apply different abrasive conditions during each test, the abrasion wheels were covered with different grit sandpapers (360, 800 and 1000 grit).

3 Results and discussion

3.1 Nanosilica particle dispersion state in the polymeric matrix

The dispersion states of colloidal and pyrogenic nanosilica particles in the polymeric coatings are revealed from TEM micrographs. The colloidal nanosilica particles are around 20 nm in diameter with narrow particle size distribution, while the pyrogenic ones present some aggregates with dimensions ranging from 30 to 200 nm.

3.2 Erosive resistance of nanocomposite coatings

The effect of nanosilica type on the erosive behavior of the coating samples is evaluated and shown in Fig.1. In general, when using the sharp-edged erodent, the nanosilica type has little influence on the mass loss of the coating samples, whereas when using the round erodent, the pyrogenic nanosilica particles offer the coating much better erosion resistance than the colloidal ones, especially when the coatings are tested at higher impingement angles. It is evident that the effect of nanoparticle type on the erosion wear resistance highly relies on the type of the erodent; the nanoparticle type plays only a minor role in determination of the erosion wear resistance at the harsh erosion testing condition (using the sharp-edged erodent). The SEM micrographs of worn surfaces of nanocoatings when using round erodent are displayed in Fig.2. Surface fatigue was occurred.
under the repeated impact of the round erodent; moreover, the worn surface is relatively smooth for the pyrogenic coating than for the colloidal one.

3.3 Abrasive resistance of nanocomposite coating

With changing of the sandpaper grit from 360 to 1000, the specific wear rates of these two coating samples (both colloidal and pyrogenic) are examined. Fig. 3 shows that the specific wear rates of coatings dramatically decrease with increasing of nanoparticle contents, regardless of the nanosilica particle type. Additionally, the R7200 pyrogenic nanocoatings show superior abrasive wear resistance than the colloidal ones at the same content.

Worn surfaces were studied using a SEM to give an insight into the abrasive wear mechanisms about the nanocoatings. Fig. 4a shows that neat polymeric coating tends to produce coarse worn surface with numerous polymer fractures, ploughed furrows and debris probably due to the micro-cutting and micro-polowing actions of the hard abrasive particles. Comparatively, in the cases of nanocoatings in Fig. 4b-c, the polymer fracture phenomenon occurred not so serious. They present only some cracks and small debris, which are formed likely due to micro-cracking and fatigue of the surface.

3.4 Micro structures of pyrogenic nanosilica particles

From the aforementioned results, the pyrogenic coating samples show better surface fatigue resistance and higher erosive, abrasive wear resistance than colloidal ones. As the colloidal nanocoatings possess better dispersion state, we find that the superior wear resistance of the pyrogenic ones was attributed to the flocc-like micro structures of the pyrogenic nanoparticles in the matrix which is beneficial for the nanoparticle-matrix interaction.

Fig.1. Mass loss as a function of impingement angle when the nanosilica particle content set as 10 wt%: (a) using sharp-edged erodent, (b) using round erodent.

Fig.2. SEM micrographs of the worn surfaces of nanocoatings when using round erodent: (a) with 10 wt% colloidal nanosilica particles, (b) with 10 wt% pyrogenic nanosilica particles.

Fig.3. Specific wear rate of the colloidal and pyrogenic coating samples as a function of the nanosilica particle content under counterpart of (a) 360, (b) 800 and (c) 1000 grit sandpaper.

Fig.4. The SEM micrographs of the worn surfaces of coating samples after the abrasion tests with counterpart of 360 grit sandpaper: (a) neat coating, coatings with (b) 25 wt% colloidal nanosilica and (c) 20 wt% pyrogenic R7200 nanosilica particles.

References
