Wear 328-329 (2015) 132–139

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

Solid particle erosion of a coating composed of clay in a polystyrene matrix☆

C.A. Márquez-Vera [a], J.R. Laguna-Camacho [b,*], A. Marquina-Chávez [b], G. Juárez-Morales [b], C.M. Calderón-Ramón [b], M.A. Morales-Cabrera [a], M. González-Lee [c], H. Martínez-Gutiérrez [d]

[a] Universidad Veracruzana, Facultad de Ciencias Químicas, Av. Venustiano Carranza S/N, Col. Revolución, C.P. 93390 Poza Rica, Veracruz, Mexico
[b] Universidad Veracruzana, Faculty of Electric and Mechanical Engineering, Av. Venustiano Carranza S/N, Col. Revolución, C.P. 93390 Poza Rica, Veracruz, Mexico
[c] Universidad Veracruzana, Faculty of Engineering in Electronics and Communications, Av. Venustiano Carranza S/N, Col. Revolución, C.P. 93390 Poza Rica, Veracruz, Mexico
[d] Centro de Nanociencias y Micro y Nanotecnologías, Unidad Profesional "Adolfo López Mateos", IPN, Luis Enrique Erro S/N, Zacatenco, C.P. 07738 México City, D.F., Mexico

ARTICLE INFO

Article history:
Received 15 October 2014
Received in revised form
29 January 2015
Accepted 3 February 2015
Available online 11 February 2015

Keywords:
Erosive wear
Montmorillonite (MMT) clay
Clay/crystal polystyrene-PS coating
Wear mechanisms

ABSTRACT

In this work, erosion tests were carried out to study the wear resistance of a coating made of montmorillonite-MMT clay in a crystal polystyrene-PS matrix. The MMT clay was modified and purified with bromide quaternary salts (hexadecyltrimethyl ammonium chloride). The coating preparation was by liquid via dissolving 25% crystal polystyrene in a solution of 70% ethyl acetate and 30% acetone, after this, modified montmorillonite was added and the coating application was by immersion of the substrate (AISI 6061 aluminium) in the liquid phase polymer coating. The substrates were coated with five layers of coating and the percentage of montmorillonite varied between 0.7–1.5 wt%. An erosion rig similar to that shown in ASTM G76-95 was used to perform the tests. The glass bead particles had a particle size between 200–240 μm. Tests were carried out using impact angles, 30°, 45°, 60° and 90° with a velocity of 2.5 ± 0.5 m/s. The abrasive flow rate was 5.0 ± 0.5 g/s. The room temperature was between 35 °C and 40 °C. Chemical compositions of the particles, substrate and the coating were obtained using energy dispersive X-ray analysis (EDS). In addition, SEM images were used to identify the wear mechanisms. Finally, AFM was used to obtain the 3D roughness profiles of the coating surface before tests.

1. Introduction

Erosion is a wear mode caused by particles impinging against a target and causing the displacement or removal of material. Erosion had been reported as a problem in diverse mechanical components such as aero gas turbines, rocket nozzles and transport tubes, fan, gas and steam turbine blades, bends and valves in bulk material handling applications and surfaces of bins, chutes and hoppers.

Different research works on solid particle erosion on polymers or polymer matrix composites have performed because of their interesting mechanical properties for different applications. For instance, Tilly [1] carried out a study on metallic metals and some polymers such as nylon and epoxy resin, showing the influence of the abrasive particle size, particle velocity and impact angle on the erosion results. It was observed that the erosion of these polymers was increased, as the particle size was higher up to a point where the results were independent of this parameter. In addition, the erosion rates were increased, as the particle velocity was higher for all the tested materials. In respect to the incident angle, ductile materials reached their maximum erosion rate at low incident angles whereas brittle materials near or at normal incidence (90°).

In addition, Tilly and Sage [2] conducted erosion tests on diverse materials such as metals, plastics and ceramics to study the influence of particle velocity and abrasive particles on the erosion results. In respect to the plastics, the type 66 nylon presented a poor erosion resistance, it was reinforced by either glass or carbon fibres. On the other hand, tests on the unreinforced epoxy were not satisfactory because of its high fragility. However, the best results were reached for the reinforced epoxy resin with

☆This article was presented at the 2nd International Conference on Abrasive Processes.

* Corresponding author. Tel.: +52 7828865337.
E-mail addresses: jlaguna@uv.mx, juanrodrigo.laguna@gmail.com (J.R. Laguna-Camacho).

http://dx.doi.org/10.1016/j.wear.2015.02.005
0043-1648/

steel powder particles. Another aspect to consider in this work was the extent of the damage on the specimen surface, which occurred by the disintegration of abrasive particles (glass spheres) during the impact. The glass fragments circulated along the surface in a radial wash incurring a secondary damage area. This effect was observed at 30° and 90° incident angles.

On the other hand, Thai et al. [3] reported erosion tests on polystyrene (PS) where the existence of two erosion peaks was due to the characteristics of the material itself. The occurrence of two erosion damage peaks could be explained by considering two different erosion mechanisms between the low and high incident angles as two erosion peaks near the impact angles of 20° and 50° were found. The mechanisms that were identified at 20° were quite typical of the erosion process but a new mechanism was described as "ring pattern erosion" at 50°. This damage pattern was seen over the attack angles of 30–70° at the impact velocity of 20 m/s.

Roy et al. [4] performed solid particle erosion tests on four different polymer matrix composites, reinforced with glass fibres, such as glass epoxy resin, glass phenolic resin (modified), glass phenolic resin (unmodified) and glass polyester resin. The results showed that glass epoxy resin (brittle behaviour) had the maximum erosion resistance at all impact angles and impact velocities compared with the other three composites whereas the modified glass phenolic resin (brittle behaviour at low velocity and ductile behaviour at high velocity) displayed the poorest erosion resistance.

Arjula et al. [5] reported the solid particle erosion behaviour of six types of high-performance thermoplastic polymers, polyetherimide (PEI), polyetheretherketone (PEEK), polyetherkethone (PEK), polyphenylene sulphide (PPS), polyethersulfone (PES) and polysulfone (PSU) and compared with ultrahigh molecular weight polyethylene (UHMWPE), a general wear resistant polymer. The main objective of the work was to explore the correlation between erosion rate and mechanical properties of neat polymers. The results showed that all polymers reached their maximum erosion rate at 30°, considerably reducing the erosion damage at 90°.

Zhou, et al. [6] studied the tensile strength, elongation at rupture and the erosion resistance of polyurethane matrix composites reinforced with alumina (Al_2O_3) particles. The results showed that the tensile strength and elongation of rupture were decreased as the alumina contents was increased. In relation to the erosion resistance, the composites reached a maximum erosion resistance and then this reduced considerably as the Al_2O_3 particles content was increased.

In other work, Zhou, et al. [7] presented a work on erosive wear of a polymer matrix (polyacrylate) coating reinforced with nanosilica particles (colloidal and pyrogenic). Two different abrasive particles were employed to perform the erosion tests, sharp-edged steel particles and round steel particles. The reinforced polymer coating with both colloidal and pyrogenic nanosilica particles exhibited a brittle behaviour reaching their maximum erosion rate at 90°. The nanosilica variations only affected the erosion results as sharp-edged particles used to conduct the testsit because the erosion rates were reduced considerably as the nanosilica content was increased. On the other hand, the erosion rates were consistent with round particles, only a slight increase in erosion was observed in the last part of the test.

In this research work, the main purpose was to determine whether suitable erosion resistance could be achieved by coating an aluminium alloy (AISI 6061) with a polymer composite containing additives of locally mined montmorillonite (MMT) clay. Solid particle erosion tests using an apparatus similar to that in ASTM G76-95 were conducted to establish the erosion rates of clay concentrations in multi-layered coatings ranging between 0.7 and 1.5 wt%. The following section describes the manner of coating preparation and the method of testing.

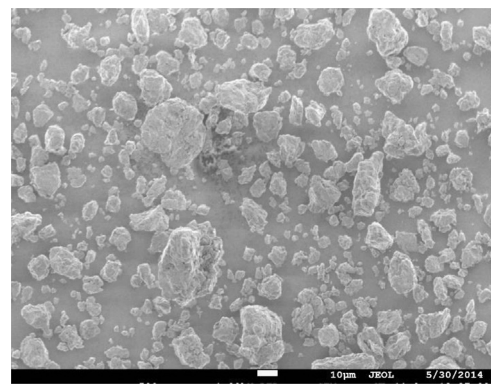

Fig. 2. Morphology of the Modified MMT clay.

Table 1
Chemical composition of unmodified and modified MMT.

Element	Unmodified MMT (wt%)	Modified MMT (wt%)
Carbon (C)	4.4	7.12
Oxygen (O)	13.13	45.32
Magnesium (Mg)	1.27	2.09
Aluminium (Al)	4.59	12.62
Silicon (Si)	7.54	24.04
Potassium (K)	1.49	5.35
Chromium (Cr)	10.47	–
Manganese	0.91	–
Iron (Fe)	44.9	2.4
Copper (Cu)	1.91	1.06
Molybdenum (Mo)	1.23	–
Nickel (Ni)	6.88	–
Zinc (Zn)	1.27	–

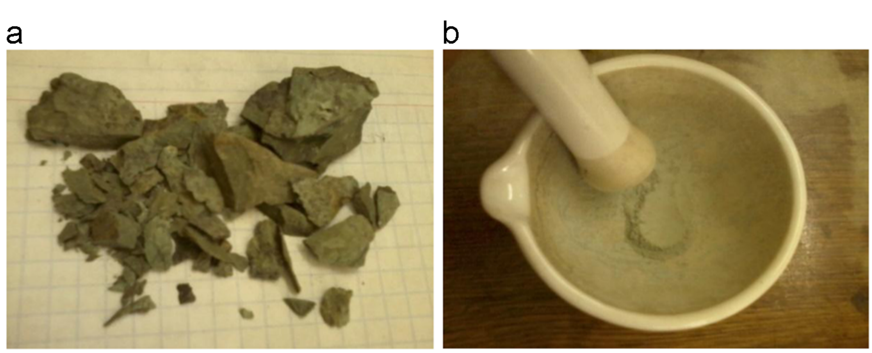

Fig. 1. (a) Natural MMT, and (b) Ground MMT.