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RESEARCH ARTICLE

EROSION BY SILICON CARBIDE PARTICLES ON HARD COATING DEPOSITED ON STEEL

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ABSTRACT

Erosion by solid particles in the coating of silicon carbide (SiC) substrates of AISI 304 stainless steel was analyzed. The specimens used were 25mm square and 3 mm thick, Silicon Carbide as abrasive particle 300-450 μm size was used. Experimental tests were performed on an apparatus developed in accordance with some parameters of the ASTM standard G76-95. Four angles of impact at 30°, 45°, 60° and 90 ° are contemplated with an approximate particle velocity of 25 ± 2 m / s with a maximum exposure time of 10 minutes per specimen, taking measurements of weight intervals 2 minutes to determine the loss of mass. The wear mechanisms were identified that these small angles were: Plastic deformation, displacement of material, plow mechanisms. While at higher angles they were present mainly: Cuttings, pitting, fractures and microcracks. It was observed that the rate of erosion depends on the angle of incidence of the abrasive particles.

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INTRODUCTION

The erosive wear is a process which occurs progressive loss of material due to the impact of solid particles, a liquid or a gas onto a surface (Buckley, 1981). Examples where happen this phenomenon is in: molding boxes, hearts casting, pipelines carrying liquids or gases, pipe fittings such as elbows, connections "T" valves, ramps used in sorting machines grains (rice, corn, peas, coffee, etc.), turbine blades, helicopter propellers, paints, coatings, automobile and motorcycle dampers, among other components (Handbook of Plasma Processing Technology, 1990). Reboundings of this particles, causing more damage by erosion on surface at the same time, when is more severe leading to a thinning of material, irregular borders and degradation. It is therefore important experimental work to provide information about the behavior of different materials and coatings to evaluate their resistance erosion phenomenon. Analysis of eroded material allows understand the erosion, among other important aspects as to know the time life of mechanical components affected and improve materials of equipment in order to reduce death times, energy losses and materials, to lending to decrease costs in the production process. A coating is an effective method for improving the durability of a material that is exposed to different conditions. A hard layer on relatively soft substrate, provides better protection against abrasion, scratching and erosion, particularly caused by the landslide, impact of hard particles. The most successful application to date is the use of ceramic coatings to coat cutting tools, allowing them to significantly increase their service life (Baldenebro Castillo, 2011). New techniques for deposition of hard coatings have been developed in the last two decades offering a variety of possibilities in the use of materials for coatings. Chemical Vapor Deposition (CVD) technique often used for coatings SiC to form dense structures, using the chemical decomposition of gases. The gas carries the components to be deposited onto the surface of a substrate which is thermally activated reaction occurs favoring synthesis of a thin film. Advantage of the CVD technique is that can be coated irregularly shaped areas uniformly and thicknesses as thin and thick layers (Pierson, 1999). Several studies have shown that the impact of solid particles by brittle materials is a type of elastic-plastic (Lawn*et al*., 1980) fracture. These

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fractures give rise to plastic deformation and cracks in the surface and lateralarea. Other studies on the TiN coating, (JR Laguna-Camacho, *et al*., 2014) subject to erosion by using SiC as abrasive particle with measures of 300-450 µmsize, the tests were conducted at different angles: 30 °, 45 °, 60 °, 90 ° and at a speed of 24m / s. The results show that TiN coating has a maximum rate of erosion at an angle of 30 °, which has a ductile type behavior. Although by SEM can be identified wear mechanisms characterized by brittle fracture due to the high coating hardness, radial cracks, chipping and crater of different sizes were also observed.

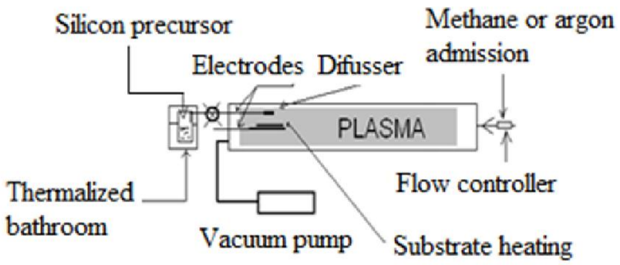

Figure 1. Schematic of the plasma CVD reactor

In this study tests were performed erosive wear by solid particles of SiC in the SiC coating deposited by the technique of chemical vapor deposition (CVD) on substrates of 304 stainless steel, used in manufacturing. The main objective of this work was to analyze the behavior and erosion resistance of the SiCcoating and to identify the different wear mechanisms.

EXPERIMENTAL DEVELOPMENT

The coating of SiCused in the development of this study had thickness of about 5microns. It was deposited using the PECVD technique (Plasma Enhanced Chemical Vapor Deposition) (Lasorsa *et al*., 2012) with asource of electrical potential continuous discharge (discharge globe) of 900 volts. The reactor consists of apyrexglass tube 80 cm long and 15cm internal diameter. The Figure 1, displays schematic of the plasma CVD reactor. The precursor used was hexamethyldisilazane (HMDS) - CH3SiNHSiCH3, process gases used were methane (CH4 UAP, ultra high purity) and UAP argon, the substrate temperature 500 ° C, heated by an internal electrical resistance placed in the substrate holder, the deposition times ranged from 15-60 min to determine the rate of coating deposition. The optimum operating pressure was 100 Pa, This configuration induces ionization processes monomer gas phase as it passes through the area of generation of plasma, and contacting the methane the immediate area of the substrate (Lieberman, 1994; Bunshah *et al*., 1982; Schuegraf, 1988) see Figure 1.The specimens used were square shape, they made of AISI 304 stainless with the following dimensions: 2.5 x 2.5 cm and a thickness of 3mm, Micro hardness of the coated material, was measured by Vickermicrohardness with diamond indentor LECO brand 1.Mod. LM 700, was used 20 measurements in differents points of the material, applying a load of 300 gf. The average hardness was of2700 HV. Figure 2 shows the indentation on the SiC coatings.

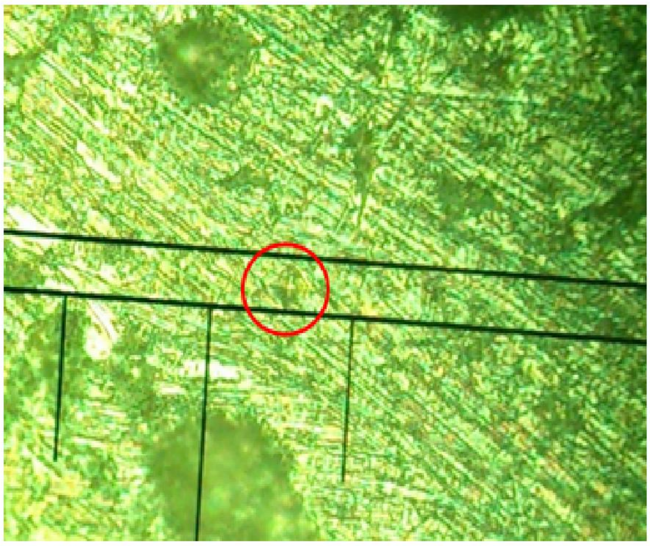

Figure 2. Vickers Indentation coating on SiC

The chemical analysis by ED show the composition of SiC, coatingcan be observed in Figure 3. This was done by SEM Brand Quanta 3D Feg-Fei JSM 7800-chemical analysis Jeol. Where high Si content and fewer C is observed, other chemical elements in the analysis as Cr, Fe, this is due to the electron beam impact when the coating surface was able to reach the part of the substrate (Martínez Arriero, 2015). Furthermore, SiC abrasive particle has an angular shape, shown in Figure 4, were used to produce erosive wear and evaluate performance of the SiC coating under severe conditions. The particle size distribution was obtained using a particle size analyzer brand BECKMAN COULTER LS 230 laser diffraction. Figure 5 shows the corresponding graph of the distribution of particle size, where it can be seen that more consistent grain size was 350-450 microns. Moreover, the average size was found to be 356 microns with a standard deviation of + 1.361µm.

TEST PROCEDURE

EPS tests were carried out using some parameters in ASTM G76-95 (G76.-95. 2000) standard. Figure 6, shows a schematic diagram of equipment employed. This prototype works using air pressure of 55 psi for the impact velocity of 25m / sec. the abrasive suction is due to the abrasive effect created by the change of pressures that are present in the venturi.

The mixture of abrasive particles and pressurized air impinges on the specimen by a nozzle located at a distance of 10 ± 1 mm. The device designed to measure the velocity of the abrasive particles, Figure 7, is based on registration of infrared light by phototransistors shaped configuration with a photo-switch barrier, thus, voltage variations experienced by the phototransistor, are produced by the interruption of the light beam by the flow of air and abrasive, which passes through the nozzle or outlet. A microcontroller measures the time it takes a signal to be register for both sensors. The speed is calculated by dividing the distance between the receivers and the time registered (Huerta Barrera, 2015).

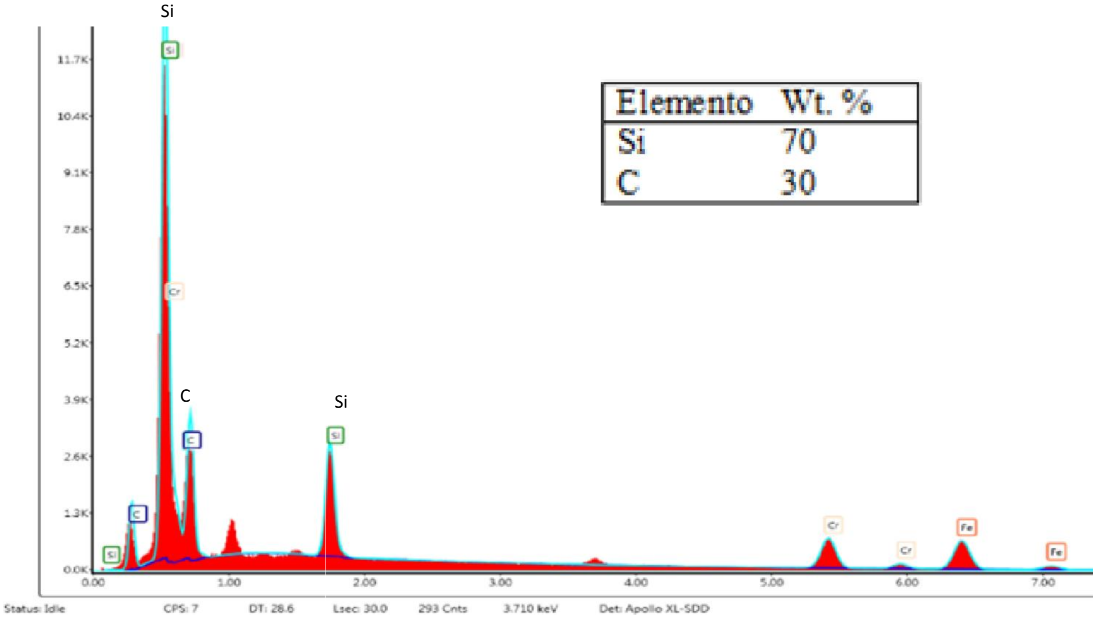

Figure 3. Chemical analysis of SiC obtained by the technique EDS

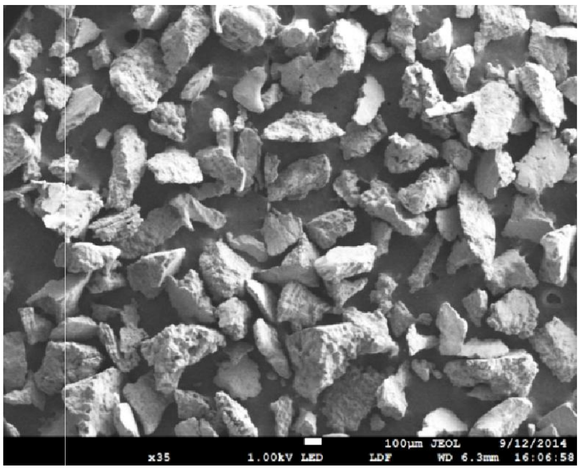

Figure4.SiliconCarbide particles

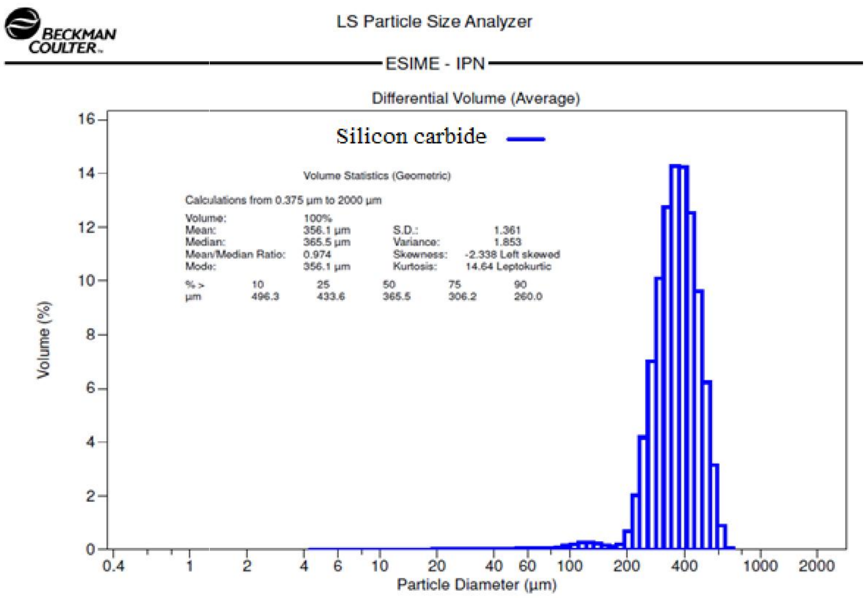

Figure 5. Distribution of particle size of SiC

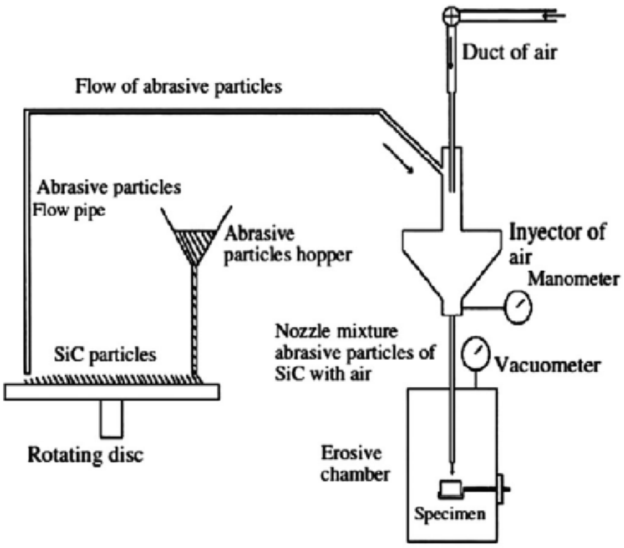

Figure 6. Schematic eroding prototype

Figure 7. Device for measuring particle velocity

Experimental tests were carried out at room temperature every two minutes until atotal of 10minutes before the start of each test, the weight is registered using analytical balance SCIANTECH,A310withaccuracy of ±0.0001g, and this procedure is repeated untila total of 5trials. Four angles of30 °, 45°, 60 °and90°were studied to examine the surface damage of the samples. The flow ofsilicon carbide abrasive was 85±2.5g/ min.

RESULTS AND DISCUSSION

Figure 8 shows the SEMimage of SiCcoatingerodedan impact angleof90°.Thewear mechanisms that can be seen are the formation of somecraters, such as pitting, in some areas of the material, plastic deformation, cracks, and fracture. With respect to an impact angleof30°, see Figure 9, there was more material loss, therefore its behavior was ductile type. The wear mechanisms were characterized by higherplastic deformation, with classic actionofmicro-cutting, micro-plowing and pitting.

The coating of SiC, due to its high hardness typically exhibit brittle fracture damage with cracks on the surface. However the silicon carbide particles may have reached the substrate surface.

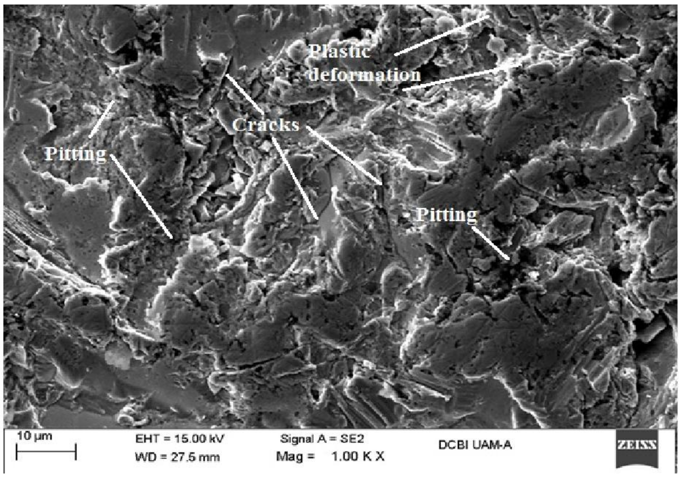

Figure 8. a) Damage by erosion of the coating at 90 °

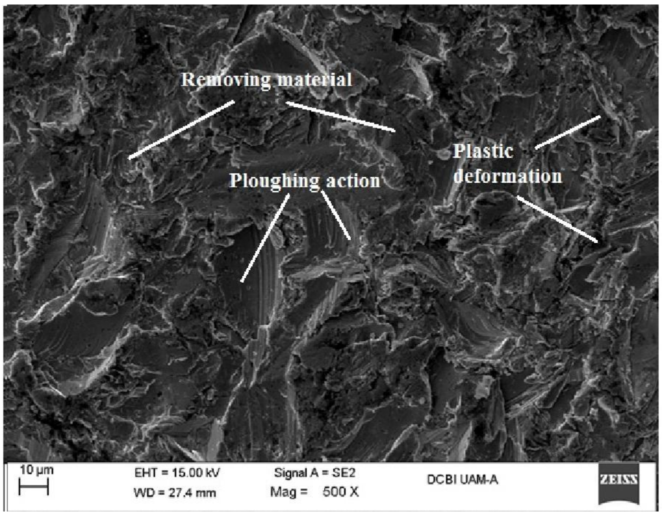

Figure 9. a) Damage from erosion coating 30°

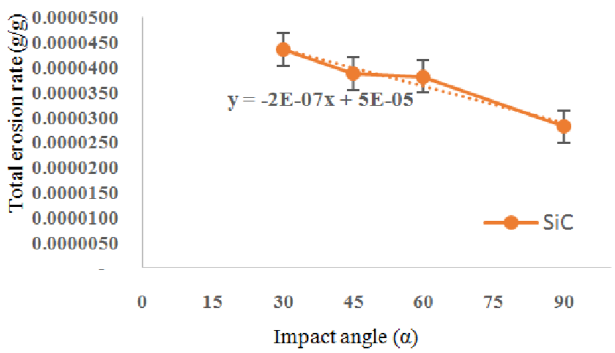

Figure 10. Graph of erosion rate of the coating of SiC

The loss of material of SiC coating at impact angles90, 60°, 45°and30°shows that if angle is decreased, the mass loss increased it means that to an impact angle of 30 °there was increased erosion wear, i.e. that coating exhibits behavior of ductile type as indicated in the literature (Finnie *et al*., 1992). Total erosion rate is calculated by dividing the total mass loss by the mass of eroding during the exposure time of the test was

10 minutes. A higher rate of erosion is achieved at an angle of 30°, whereas the lowest rate occurs at an angle of 90°.It can be observed in Figure 13.

It is observed that the scars wear greater generated on coating of SiC showed an incidence angle of 30°, whereas at 90° surface damage has a nearly circular shape, unlike the other angles that tend to elongate acquiring an elliptical appearance, see Figure 11.

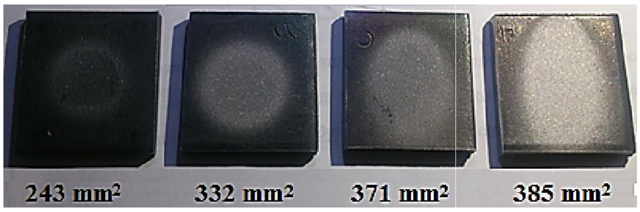

Figure 11. Traces generated by particles of SiC on SiC coating at an angle of impact: a) 90, b) 60, c) 45, d) 30 °

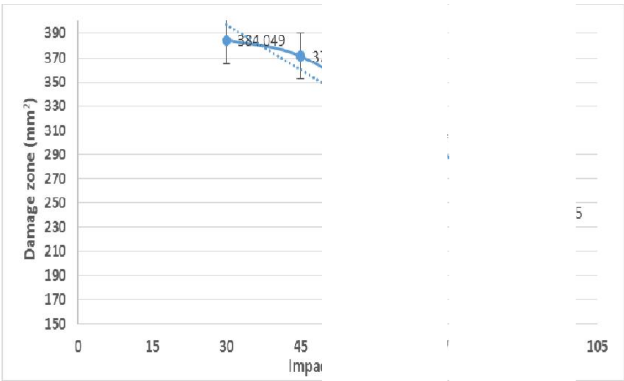

Figure 12. Dependence of the damage zone on the impact angle

Figure 12 shows the changes in the damage zone with respect to the incident angle. A higher damaged zone was observed at 30◦ whereas a considerable reduction is seen at 90◦.

Conclusion

This work allowed to know the behavior of the SiC coating deposited on AISI steel 304substrates subjected to the phenomenon of erosion, using SiC as abrasive particle. It can be considered that the wear rate of the coatings presented in used will depend on the angle of impact in which at 30° angle was greater wear, while at 90° was lower erosive wear. The wear mechanisms present were, plastic deformation, displacement of material, plow mechanisms, at low angles and cutting mechanisms, pits, micro cracks at larger angles. Erosive wear charts hat were obtained showed SiC coating generally ductile behavior type, as demonstrated by different authors and typical graphic ductile and brittle behavior of materials (Finnie *et al.*, 1992).

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