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Tribological and Corrosion Behavior of Multilayered WC-$Ti_{1-x}Al_xN$ Coatings Deposited by Cathodic Arc Deposition Process on High Speed Steel

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1. ABSTRACT

Recently, many of the current development in surface modification engineering are focused on multilayered coatings. Multilayered coatings have the potential to improve the tribological and corrosion properties of tools and components. By using cathodic arc deposition, WC-$Ti_{1-x}Al_xN$ multilayers were deposited on steel substrates. Wear tests of four multiplayer coatings were performed using a ball-on-disc configuration with a linear sliding speed of 0.1m/s, 5N load. The tests were carried out at room temperature in air by employing AISI 52100 steel ball (H_v = 848N) of 11mm in diameter. Electrochemical tests were performed using the potentiodynamic and electrochemical impedance spectroscopy (EIS) measurements.

The surface morphology and topography of the wear scars of tribo-element and the corroded specimen have been determined by using scanning electron spectroscopy (SEM). Also, wear mechanism was determined by using SEM coupled with EDS.

Results have showed an improved wear resistance and corrosion resistance of the WC-$Ti_{1-x}Al_xN$ coatings.

2. EXPERIMENTAL PROCEDURE

WC-$Ti_{1-x}Al_xN$ coatings were deposited on Si wafer and AISI D2 steel by cathodic arc ion plating. The prepared samples are designated as WC-$Ti_{0.6}Al_{0.4}N$, WC-$Ti_{0.53}Al_{0.47}N$, WC-$Ti_{0.5}Al_{0.5}N$ and WC-$Ti_{0.43}Al_{0.57}N$. All substrate were polished using 2000 girt SiC for the final step. A total coating thickness of 2.1㎛ was aimed at in all cases. To evaluate the adhesion of coatings, a scratch tester was used to determine a critical load. A loading rate 10 N/min was utilized. The critical load (L_c) is defined as the smallest load at which the coating is damaged. The coating hardness was measured using a Knoop hardness tester with a load of 10g.

Ball-on-disc configuration tribometer was employed to investigate the wear behavior of the WC-$Ti_{1-x}Al_xN$ coating. The tests were carried out by employing AISI 52100 steel ball of 11mm in diameter in the sliding tests. Steel balls were cleaned in an ultrasonic acetone bath before the tests.

The wear experiments were performed in air, without lubrication, at a temperature of 298K. A load of 5.38N was used and a sliding velocity of 0.017m/s. Sliding distance was kept at 155.6m.

The wear mechanism was determined by using SEM coupled with EDS.

Polarization measurement was carried out potentiodynamically in 3.5% NaCl electrolyte at room temperature. Potentiodynamic polarization scans and EIS tests were obtained using an EG&G PAR 273A and EG&G Model 1025. A saturated calomel and a pure graphite were used for reference electrode and counter electrode. The potentiodynamic polarization tests were carried out with a scan rate of 0.166mV/sec. EIS measurements were performed at E_{corr} after immersion in a 3.5% NaCl solution. A perturbation AC potential of amplitude 10mV sine-wave was applied over frequency range between 100kHz and 5mHz using a logarithmic sweeping frequency of 5steps/decade. The impedance diagrams were interpreted on the basis of equivalent circuits using the Z-view.

3. SUMMARY OF RESULTS

A majority of the coatings exhibited a very dense and columnar structure for the cross-section morphology. Also, it has been found that the amplitude of the surface irregularities (small craters and droplets) decreases with increasing aluminium content. Adhesion critical loads (L_c) up to approximately 52N were obtained for the best samples (WC-$Ti_{0.5}Al_{0.5}N$ and WC-$Ti_{0.43}Al_{0.57}N$). Increasing the aluminium content exhibits a range of 87~90H_K and to the formation of a dense multilayered coating. WC-$Ti_{0.43}Al_{0.57}N$ coating with a lower width of wear scar has superior sliding wear resistant property. From the EDS analysis, the analysis of the wear debris revealed aluminium, iron, and oxygen elements. Usually, oxides are known to present friction reducing capabilities due to their relative softness. The wear volume of counter partner (steel ball) when interacting with the four types of multilayers and AISI D2 decreases with increasing aluminium content in the coatings.

The porosity can also be determined from the measured polarization resistance. The electrochemical determinations give a porosity rate of 0.2242 for WC-$Ti_{0.6}Al_{0.4}N$, 0.1433 for WC-$Ti_{0.53}Al_{0.47}N$, 0.006 for WC-$Ti_{0.5}Al_{0.5}N$, and 0.0003 for WC-$Ti_{0.43}Al_{0.57}N$. In the present study, it was concluded that the increase of the aluminium content led to a substantial decrease in porosity. The best corrosion resistance properties were found in the WC-$Ti_{0.5}Al_{0.5}N$ coating, which also had the lowest corrosion current density, and porosity. Also, from the result of EIS measurements, after 168hr immersion time, the R_{ct} value of WC-$Ti_{0.43}Al_{0.57}N$ coating is lower than others.

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