Sliding wear behaviour and hardness properties of nickel-quarry dust composite coatings

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ABSTRACT – In this project, this work focus on development of new composite coating materials by using quarry dust as reinforcement materials for nickel matrix. Nickel quarry dust (Ni-QD) composite coatings using various quarry dust content were deposited on tungsten carbide substrate by using an electrodeposition technique. The electrodeposition process was carried out for 1 hour at 40°C under the current density of 3 A/dm^2 in a modified nickel Watt's bath containing 20,40,60 and 80 g/l of quarry dust particles. The Ni-QD composite coatings were characterized using 3D profilometer. Hardness Vickers and micro pin on disc tribotester were used to test the microhardness of coating and sliding wear scar on the composite coating. Ni-QD 60g/l shows the optimum microhardness 590.37 HV. The damage of the sliding wear scar was improved, as the quarry dust content increases from 20g/l to 60g/l.

1. INTRODUCTION

With a growing demand of anti-wear and anti-oxidation coatings, nickel composite coating has attracted intensive concerns from the academicians and industries. Nickel which possesses high tensile strength and good toughness is a popular choice as a matrix material and it can disperse both soft and hard reinforcements. When compared to pure metal or alloy, hardness, wear and corrosion resistance are improved in electro-codeposited metals or alloys [1]. Electro-codeposition is an important method for producing Metal Matrix Composite (MMC) coatings by codeposition metallic, non-metallic particles with pure metals or alloys to enhance the tribological properties and resistance to corrosion [2]. In the present scenario, studies into the codeposition of ceramic particles such as SiC, Cr_2O_3, TiO_2, and Al_2O_3 along with nickel plating finds a medium for enhancing the wear resistance of plated components [3]. Because of the high percentage of ceramic particles which consists of SiO_2 and Al_2O_3, quarry dust is one of the by-products of the crushing process during quarrying activities that have gained attention to be used for various applications, such as construction industry and manufacturing of building materials industries [4].

In this study, composite coatings showed remarkable mechanical characteristics and stable microstructure with Ni–QD coating showing promising result of microhardness test. The wear rate of the composite coatings also was investigated.

2. METHODOLOGY

The 40 mm x 30mm x 3 mm tungsten carbide substrate was grinding from 240 to 1200 grit paper using silicon carbide paper. The substrate was then connected to a glass cell fitted with a water jacket, through which water was circulated from a thermostat bath at 40ºC. For nickel electrodeposition, a power supply was used using a standard two-electrode device consisting of anode electrode nickel plate (99.99%) and tungsten carbide plate on cathode electrode. The electrodeposition method was performed in a modified nickel Watt's bath containing 20,40,60 and 80 g/l of quarry dust particles at 40°C for 1 hour under the current density of 3 A/dm^2. Ni-QD characterization was conducted using 3D profilometer image for the sliding wear behaviour. Hardness and sliding wear properties of the Ni-QD composite coating were analyzed using microvickers hardness tester and micro pin on disc tribotester (CM-9109).

3. RESULTS AND DISCUSSION

a. Characterization of Quarry Dust

The elemental composition for particles from quarry dust is found by XRF technique and shown in Table 2. SiO_2 shows the dominant element on the quarry dust particles where 72.6 wt% and follow by Al_2O_3 where 15.1 wt%. SiO_2 and Al_2O_3 was significantly improving the properties of the nickel matrix composite coating.

Table 1 Composition of quarry dust particles [5]

Element	SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	Na_2O	K_2O	SO_3	TiO_2	P_2O_5
Concentration (Wt%)	72.6	15.1	1.1	1.9	0.8	3.0	4.9	0.2	0.3	0.1

b. Effect of various quarry dust content on the hardness and wear scar of composite coatings

Analysis of the microhardness revealed that the optimum content of Ni-QD 60g/l has a microhardness of 590.37 HV compared with pure nickel where microhardness 207.65 HV was achieved as shown in Figure 1. The differences observed were attributed to dispersion hardening effects cause by the presence of SiO_2 and Al_2O_3 in the composite coating. According to Lehman et al. [6], the particles act to reduce dislocation motion in the nickel matrix, which causes an increase in the hardness properties. The quarry dust particles co-deposited in the Ni matrix could restrain the Ni grains and the plastic deformation of the matrix under a loading due to maximum dispersion strengthening at quarry dust content in Ni-QD 60g/l. The effect is that the coating becomes stronger as the quarry dust content increases, thus increasing the micro hardness and wear resistance of the coating.

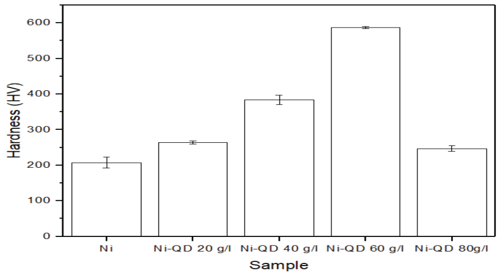

Figure 1 Microhardness of Ni-QD composite coatings

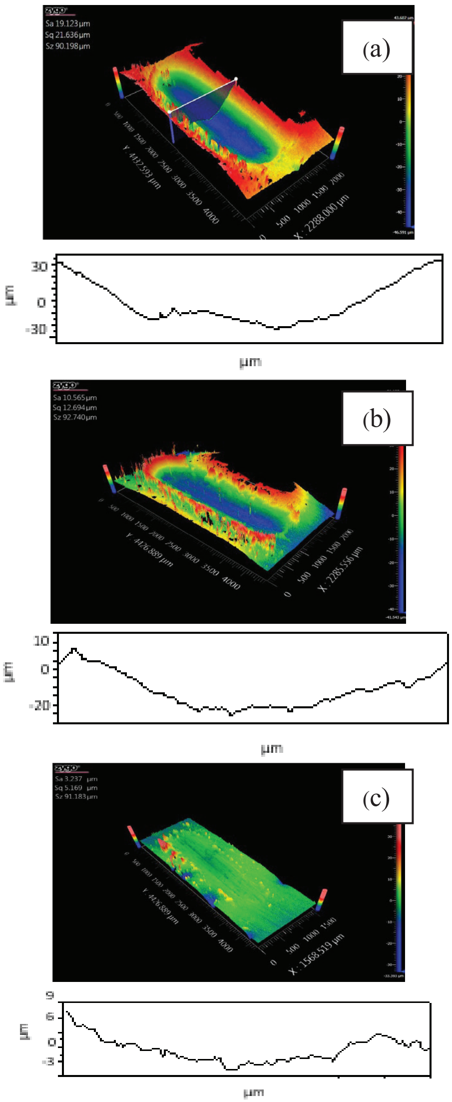

Figure 2 Surface profile of composite wear tracks at various QD content (a) 20g/l, (b) 40g/l and (c) 60 g/l

In addition, the results further revealed that quarry dust content as shown in Figure 2 had a significant effect on the wear tracks of the composite coating. The reduction in wear width and depth was attributed to the increase in SiO_2 and Al_2O_3 particles embedded in the nickel matrix during the co-deposition process. Futher increases in the quarry dust content resulted in increase of the brittleness of the coating, which is susbsequently reflected as a reduction of hardness and the wear resistance of the coating at Ni-QD 80g/l.

4. CONCLUSION

In summary, the Ni-QD 60 g/l successfully improved the wear resistance of the composite coating. This is due to the optimum content of quarry dust particles that embedded in the nickel matrix during the deposition process.

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