Comparison of wear behavior of WC-Cr_3C_2 reinforced Ni-Cr layers in dry friction and in distilled water

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Abstract. WC-Cr_3C_2 reinforced Ni-Cr layers using self-made Ni55 alloy powder were deposited on a medium carbon steel by laser cladding in this work. From the results of contrast wear tests in dry friction and in distilled water, we found that water plays few lubrication in the process of friction and wear, but it can reduce the friction coefficient and the depth of track by reducing the grinding of wear debris on the surface of clad.

1. Introduction

Composed of reinforcing phases and metal, metal matrix composites (MMC) has excellent oxidation resistance, wear-resistant property and corrosion resistance[1-4]. Laser cladding may be used to deposit MMC coatings on surfaces of ductile metal matrixs. The reinforcement phases are normally ceramic or compounds of refractory metals as titanium carbide (TiC), tungsten carbide (WC) or chromium carbide (Cr_3C_2). The matrixs usually are Ni or Co based alloys which further enhance the coating resistance to corrosion[5-11].

At present, the microstructures, mechanical properties and tribological performances of Ni based MMC have been studied, but there is less reserch of its wear behavior in water[12-14]. The aim of this work was to determine the friction and wear performance of Ni based MMC coatings in water. The reciprocating sliding tests were performed with a ball-on-disc test configuration in distilled water. The coatings were deposited on the surfaces of medium carbon steel components by means of laser cladding. The hard phases are WC and Cr_3C_2 for high hardness and good wettability by molten metals.

2. Experimental procedure

The discs made of medium carbon steel composition (wt %) as: 0.45C, 0.3Si, 0.6Mn, balance of Fe, were used as the matrix material in these experiments. The self-made Ni55 alloy powder with chemical composition as 0.5% C, 13.4% Cr, 0.1% Mn, 2.3% Si, 1.7% B, 12.5% Fe, 51.5% Ni, 13% WC and 5% Cr_3C_2 was deposited on the disks by LDF 6.000-100 laser machine (Laserline, German) . The laser processing power of 1.9kW, the rectangular beam 5mm × 5mm, the scanning speed 300 mm/min, 50% overlap in the cladding the whole process without protective gas.

With samples of suitable sizes by WEDM, FEI Nova NanoSEM 450 scanning electron microscope (FEI Company, USA) equipped with Energy Dispersive Spectrometer (EDS) was used to analyze the surface morphologies of surface and cross-section of sulfurizing composite coating. The phases of the film and composite layer were identified by X-Ray Diffraction with Cu Kα radiation. The friction and wear performance under dry friction was assessed by Cetr-UMT-3MO multi-functional tester (BRUKER company, USA), where the ceramic ball slid against the coated discs. As shown in Fig.1, the ZrO_2 ball with Rockwell hardness of 90 were mounted stationary in the upper holder and the coated discs performed the reciprocating motion. The force applied in the tests was 80N, the sliding velocity was 20m/s, the stroke length was 10mm and the test duration was 1h. The coefficient of friction was recorded during the tests.

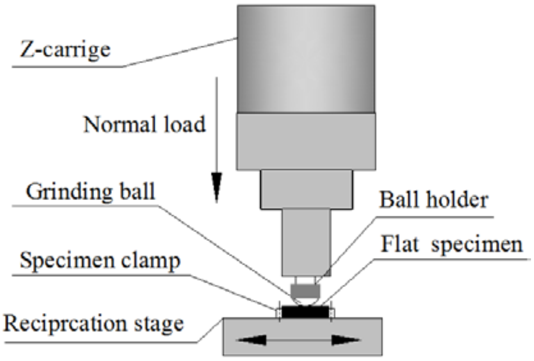

Fig. 1. Schematic diagram of UMT abrasion tester

3. Results and Discussion

3.1 Microstructure and composition of composite layer

The thickness of Ni55 (WC-Cr_3C_2 reinforced Ni-Cr alloy) clad layer was about 1.1mm without pores or cracks from the imagine of corss section (Fig. 2 a). The microstructure was not uniform across the the depth and length of the layers (Fig.2 b), and there are four typical areas in the microstructure from the SEM morphologiy of surface of Ni55 clad coating (Fig.2 c). The EDS analysis results showed that there are high chromium content in area B, and there high nickle content in the other areas (Fig.2 d).

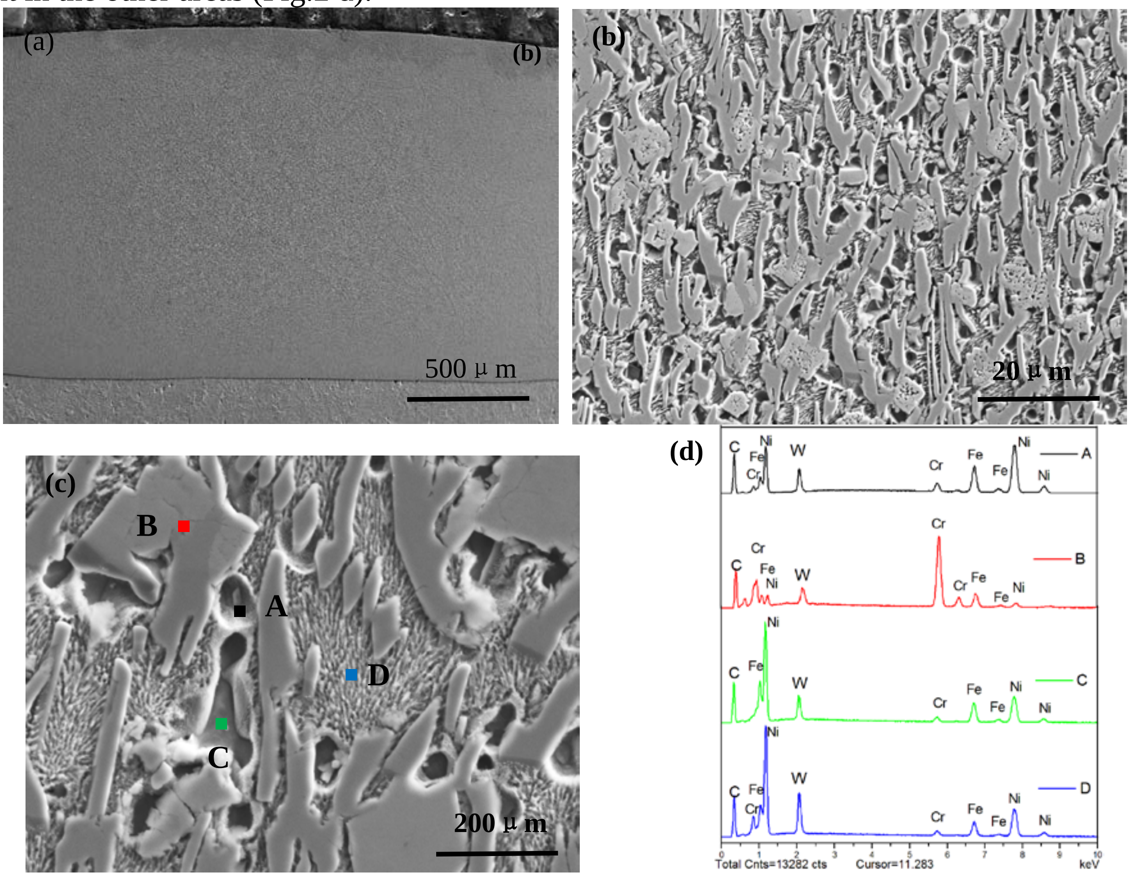

Fig. 2. OM and SEM morphologies of cross section, and SEM morphologiy and EDS analysis of surface of Ni55 clad layers

From XRD pattern of Ni55 laser clad layer (Fig.3), the primary phases are FeCr and $Fe_{0.64}Ni_{0.36}$ intermetallic compound, [Fe,Ni] solid solution, and Fe-Ni-Cr-C, the strengthening phases are W_2C, Cr_7C_3 and other carbides.

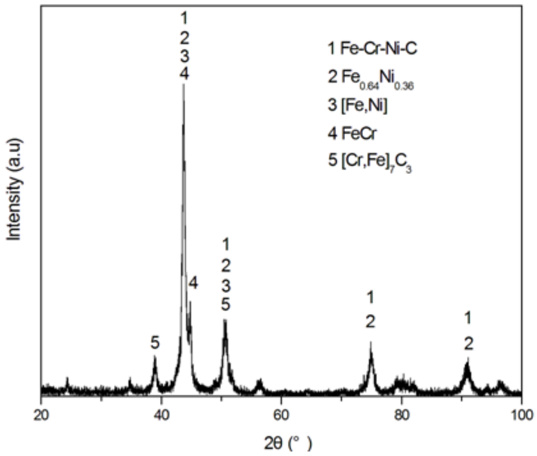

Fig. 3. XRD pattern of Ni55 clad layer

3.2 Friction and wear results

Fig. 4 showed the test results of Ni55 laser clad layer coating against ZrO_2 ball in dry friction under the load of 80N for 1h respectively. Fig. 4 a presented the measured friction coefficient as a function of the sliding speed registered during the wear test. In the case of the laser cladding, the friction coefficient increased up to 0.52 during the first few minutes of the experiment, followed by a rapid decrease to 18 minutes, and then the value increased again and becomes unstable. After that, the friction coefficient fluctuates within the small scope of 0.05 and stabilized around 0.6. In the case of the layer in distilled water, the friction coefficient increases up to 0.51 during the first minutes of the experiment, followed by a subsequent slow decrease until the value stabilized around 0.42. Fig. 4 (b) showed the wear depth of three materials when tested against the ZrO_2 ball after 1 h. As it can be observed the depth of clad layer in distilled water was 10 μ m, almost two-thirds of that in dry friction.

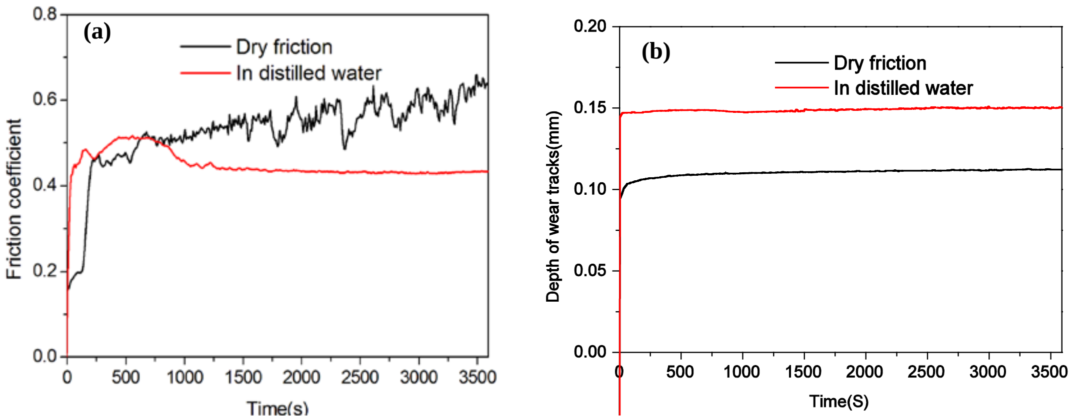

Fig. 4.The friction coefficient of Ni55 clad layer (a) in dry friction, (b) in distilled water

The wear morphologies for the clad layers in dry friction and in distilled water were shown in Fig.5. As it can be observed there were some craters formed because of continuous spalling of debris from the matrix (Fig.5 a), plenty of wear debris scattered all around the tracks and piled up at the end (Fig.5 b). It is the craters and debris that was the main mainly cause of instability of the friction coefficient. Although there were a few pockmarks and debris in case of distilled water because of fatigue spalling (Fig.5 b), but this kind of situation was improved because the debris were swept away by water. And water showed few lubrication in this experiment according to the a large number of furrows in wear tracks (Fig.5 d).

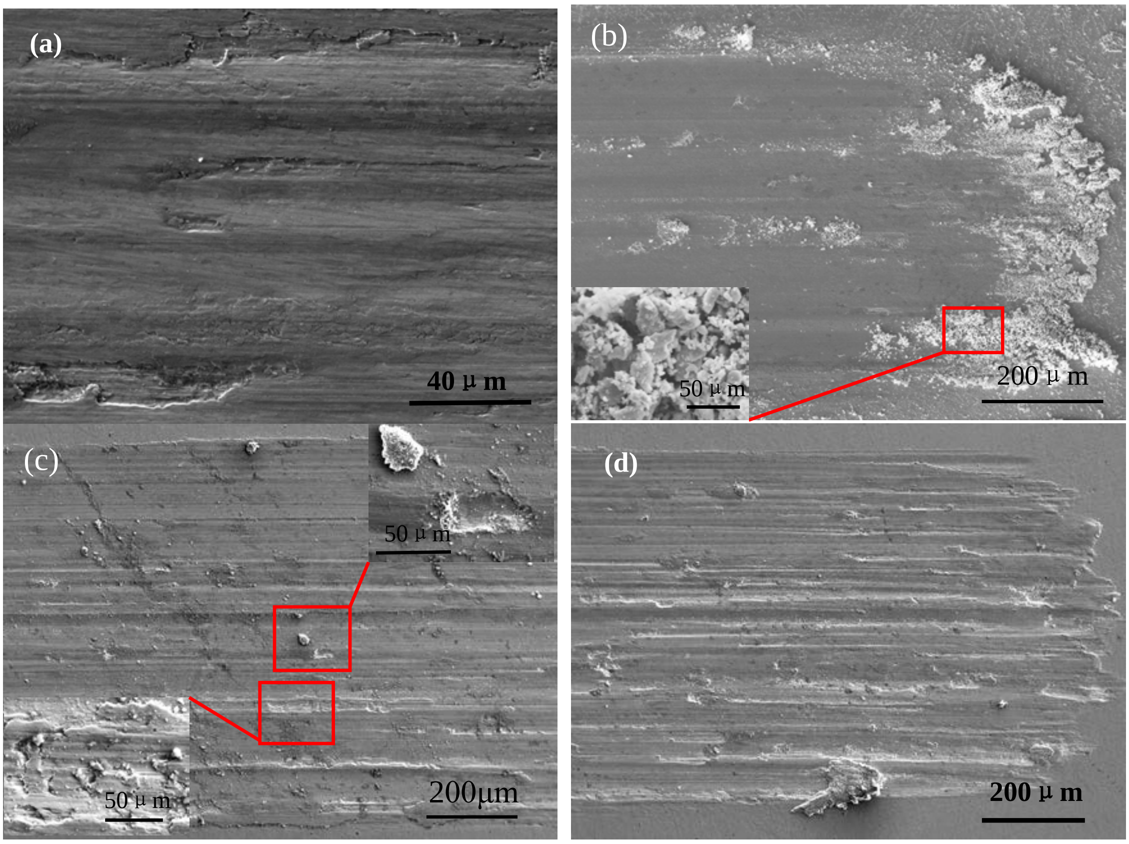

Fig. 5. Wear morphologies of Ni55 clad layer in dry condition (a)& (b), in distilled water(c)& (d)

Summary

Ni based MMC layers without pores and cracks using self-made Ni55 alloy powder were deposited on a medium carbon steel by laser cladding. From the results of contrast wear tests in dry friction and in distilled water, water can plays few lubrication in the process of friction and wear, but can reduce grinding between wear debris and clad layer by taking away debris from wear tracks.

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