Evaluation of WC-9Co-4Cr laser surface alloyed coatings on stainless steel

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Abstract. In order to examine the effect of Cr on the microstructure and hardness behaviour of WC cermets, coatings have been obtained by laser surface alloying technique. WC-9Co-4Cr particulate was injected onto the surface of AISI 304L stainless steel under different processing variables. The morphologies and microstructures of the composite coatings were investigated using optical microscopy and high resolution scanning electron microscopy, while the phase changed were observed using x-ray diffraction. The surface hardness was determined using the Vickers microhardness tester. The excessive heat from the laser beam partially melt the WC-Co which results in carbon deficiency and precipitation of carbon as graphite to form CO_2 pores within the coatings. 4% Cr has been added to compensate for the precipitation of graphite to form Cr_3C_2. A considerable increase in hardness value from 246 to 1331 $H_{v0.1}$ was achieved when alloying was carried out at high laser power and speed, the pores being completely eliminated.

1. Introduction

Tungsten carbide (WC) belongs to the group of advanced ceramic materials with great industrial importance and well known as hardfacing material with Co or Ni alloys as binders. Apart from high hardness, WC has a unique set of properties; high melting point, wear resistance, good thermal shock resistance, thermal conductivity and good resistance to oxidation [1-3].

However, WC cermets melt and dissolve in the melt pool owing to a low free formation enthalpy of 38.5 kJ/mol. According to Nerz et al, [4] depending on time and temperature WC decarburize to form W_2C, and later free tungsten and carbon. The carbon can react with atmospheric oxygen to form CO and CO_2, which had no enough time to flee from the melt pool during rapid solidification. As a result of this, porosities are formed in the composite coating [2] and this could limit the wide-scale industrial recognition of this composite.

Laser alloying gives a perfect adhesion to the interface of the bulk steel and the coating with homogeneous microstructure due to strong marangoni convection caused by surface tension gradients and high cooling rates [5, 6]. With optimum laser processing parameters, a reliable coating that is free of cracks and pores can been produced on the matrix. In this paper, WC-9Co-4Cr composite coatings were prepared on 304L stainless steel by varying the laser processing parameters.

2. Experimental methods

The specimen investigated was 304L stainless steel with dimension of 64x40x4 mm. The reinforced powder was a pure agglomerated and sintered WC-9Co-4Cr cermet as shown in figure 1.

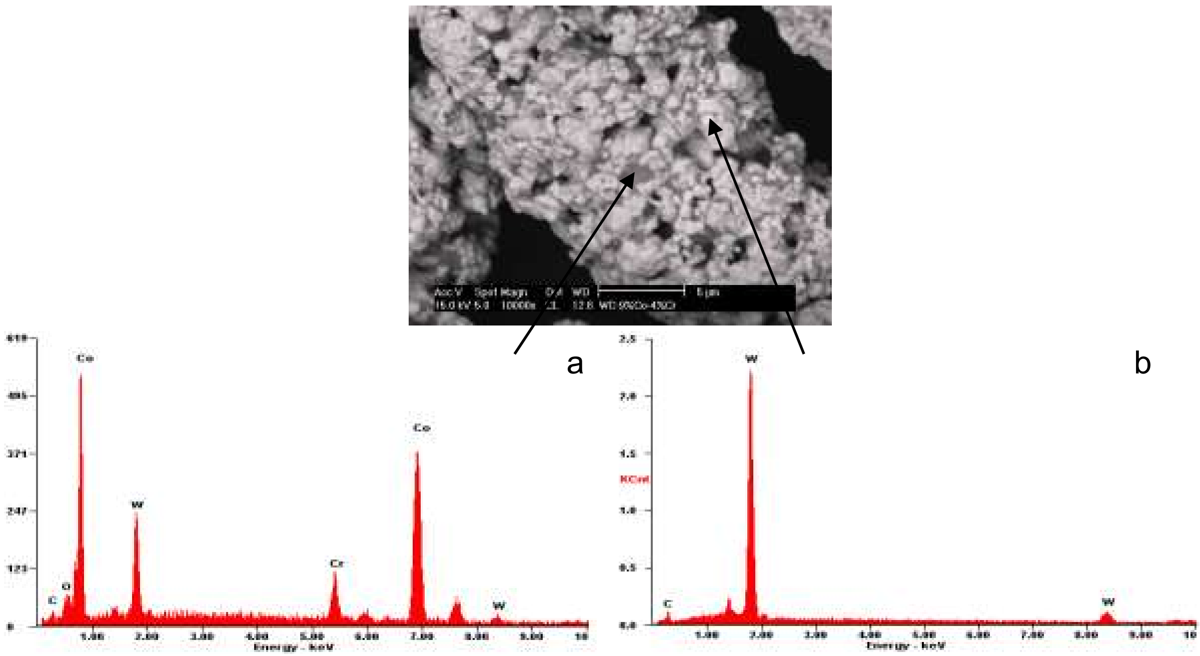

Figure 1 SEM image and EDS of WC-9Co-4Cr particle showing the (a) Co-Cr binder and (b) WC.

The average particle size was approximately 26 μm. The surface melting operation was conducted using a 4.4 kW Nd:YAG laser. The specimen surface was shielded by argon gas flowing at 2 L/min during the laser scanning to prevent oxidation. The laser beam was focused to a 3 mm diameter size, the laser power used was 2.0 kW and the scanning speed was varied from 0.6 to 1.2 m/min.

After laser injection, the coatings were sectioned, mounted and polished for metallographic examination. The phases were identified by XRD and also elements present using EDS analytical techniques. The microstructures and the distribution of hard phases were examined using SEM. Microhardness profiles of the cross section were measured using an EMCO TEST Durascan microhardness tester at a load of 100 gf.

3. Results and discussion

Figure 2 shows the SEM micrographs of the specimen reinforced with WC-9Co-4Cr at laser power of 2.0 kW and varying scan speeds of 0.6 to 1.2 m/min. The coating thicknesses for the specimens were found to be approximately 1750, 1260, 1140 and 1055 μm respectively. The variation in thickness is dependent on the speed of the laser beam. At lower scan speed, the laser beam irradiates the specimen longer, thus large and deep meltpool forms. Also due to high wettability of WC, the strong marangoni convection aids the uniform distribution of carbides in the melt pool as can be seen in figure 2.

The presence of undissolved carbides at the surface is due to rapid solidification of the melt pool. A coated layer without cracks or pores was formed on specimen 1 as shown in figure 2a. However, it was noted that pores were common in Specimen 2, 3 and 4. This could be as a result of the entrapment of gases originating from various sources [7]. From the microstructure of all specimens, metal carbides precipitated out as dendrites as shown in figure 3.

Melting, dissolution and resolidification of WC took place to form WC and $M_{23}C_6$ (M=Fe, W) as indicated in the XRD analysis in figure 4. The EDS point analysis in figure 3 confirms the presence of WC particles and also presence of M_2C particles in the matrix.

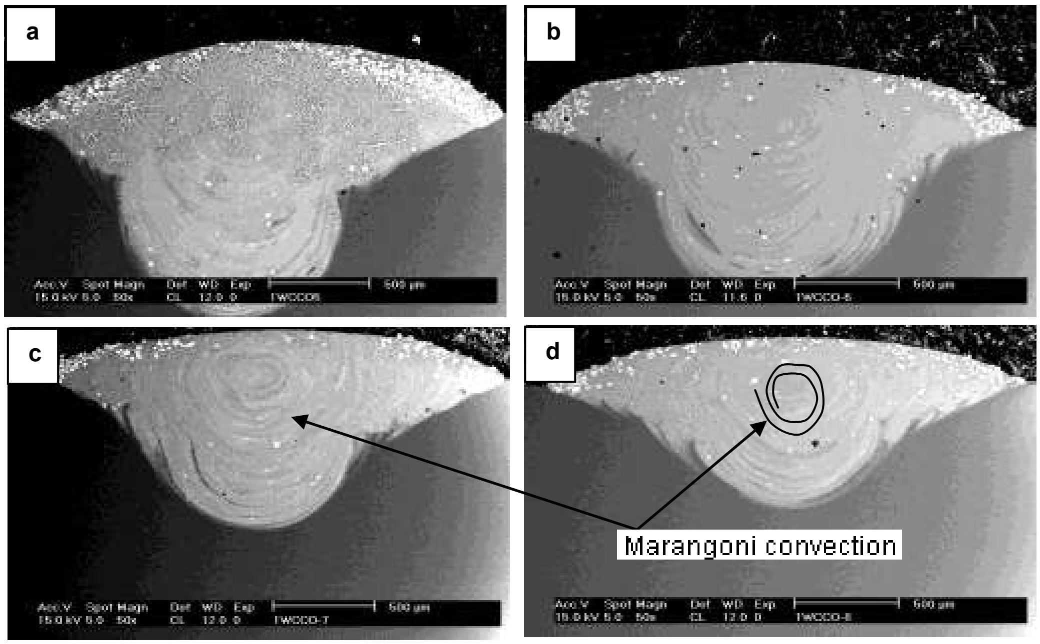

Figure 2 SEM micrograph of 304L stainless steel alloyed with WC-Co-Cr at laser power of 2.0 kW and scanning speed of (a) 0.6, (b) 0.8 kW (c) 1.0 and (d) 1.2 m/min

Microhardness measurement was performed on the specimens as shown in figure 5a with values which are a representation of 5 measurements for each laser alloyed specimen is 955, 816, 804 and 617 $H_{V0.1}$ respectively. The value of the hardness is influenced by the laser speed (figure 5b) for the entire specimen as more carbide is expected in the matrix at lower scan speed.

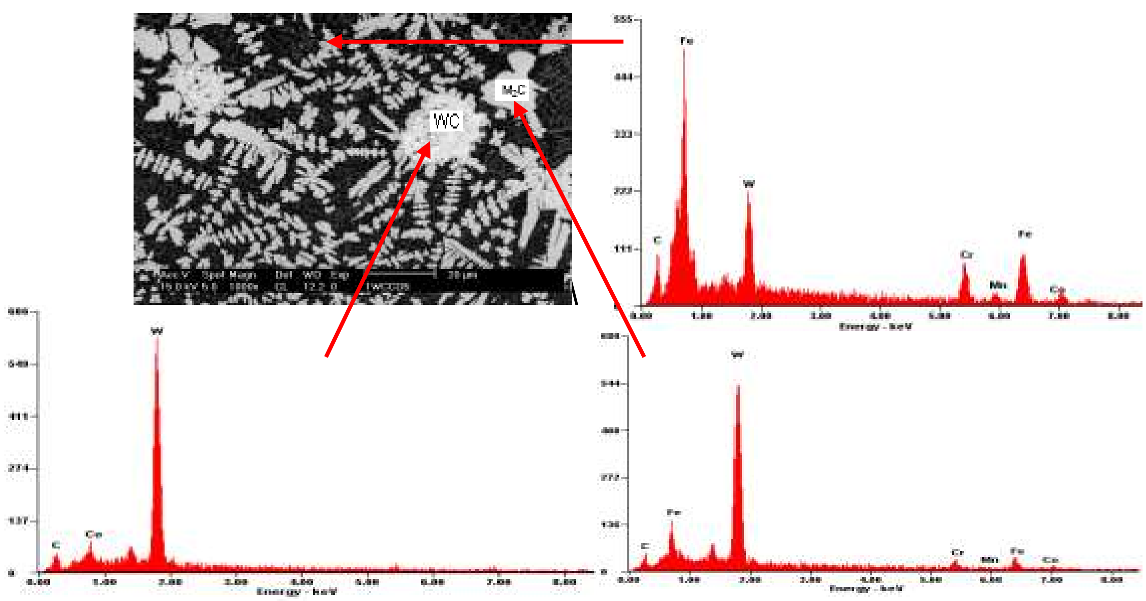

Figure 3 SEM image and EDS point analysis at laser power of 2.0 KW and scan speed of 0.6 m/min

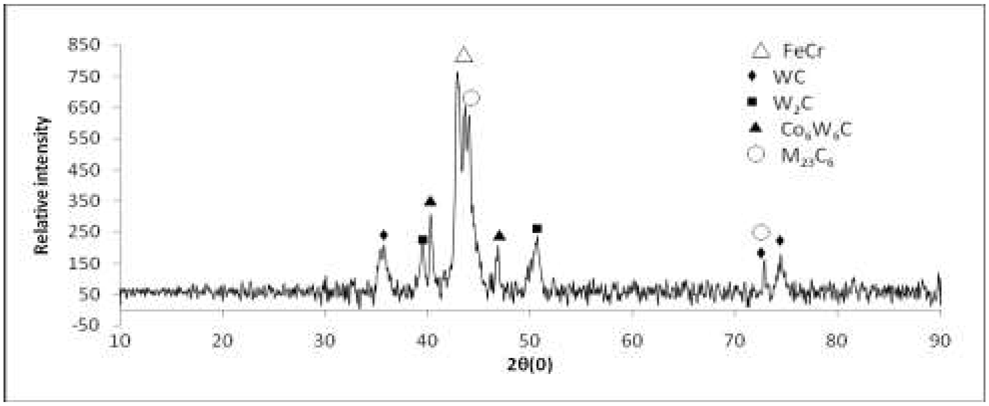

Figure 4 XRD analysis of specimen 1

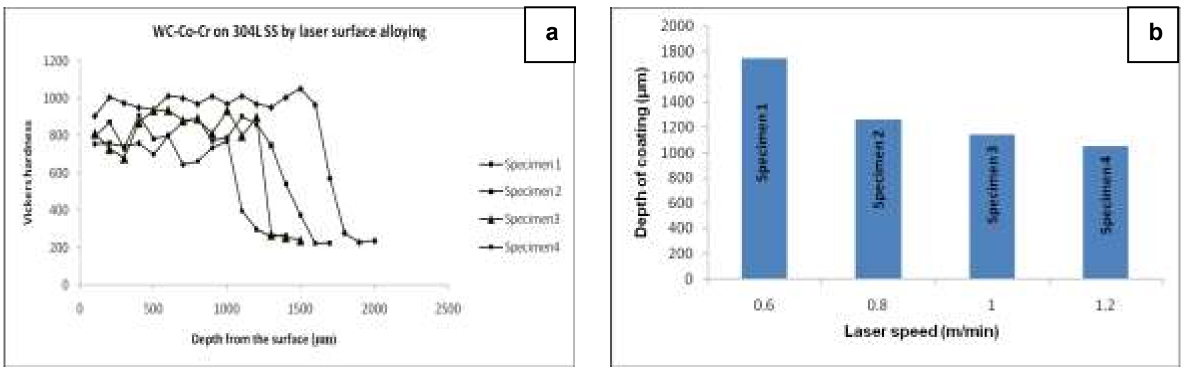

Figure 5 Microhardness distribution as a function of the thickness of the laser alloyed layer.

4. Conclusion

It has been shown that 304L stainless steel matrix composite can be prepared by laser surface alloying without pores and cracks at laser power of 2.0 kW and scan speed of 0.6 m/min. The microhardness can also be improved significantly from 246 to 1331 $H_{v0.1.}$

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