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

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Abstract. In order to examine 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 austenitic stainless steel (ASS) under different laser processing variables. The morphologies and microstructures of the composite coatings were investigated using optical microscopy and high resolution field emission scanning electron microscopy (FESEM) equipped with energy dispersive spectrometer (EDS), while the phase changed were observed using x-ray diffraction (XRD). The surface hardness was determined using the Vickers microhardness tester. The decomposition of WC-9Co-4Cr into W_2C, C and W is as a result of low heat of formation of WC and low affinity of tungsten for Carbon. Free Co and C in the meltpool formed intermetallic phases such as Co_6W_6C and $M_{23}C_6$ (M=Fe, Cr, W). A considerable increase in hardness value of the matrix 246 $H_{v0.1}$ compared to the coating 1331 $H_{v0.1}$ was achieved when alloying was carried out at 2.0 kW laser power and scan speed of 0.6 m/min.

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 melt pool formed by laser irradiation of the surface layer of the substrate due 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/CO_2, which could be trapped in the melt pool during rapid solidification. As a result of this, pores 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 ASS 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.

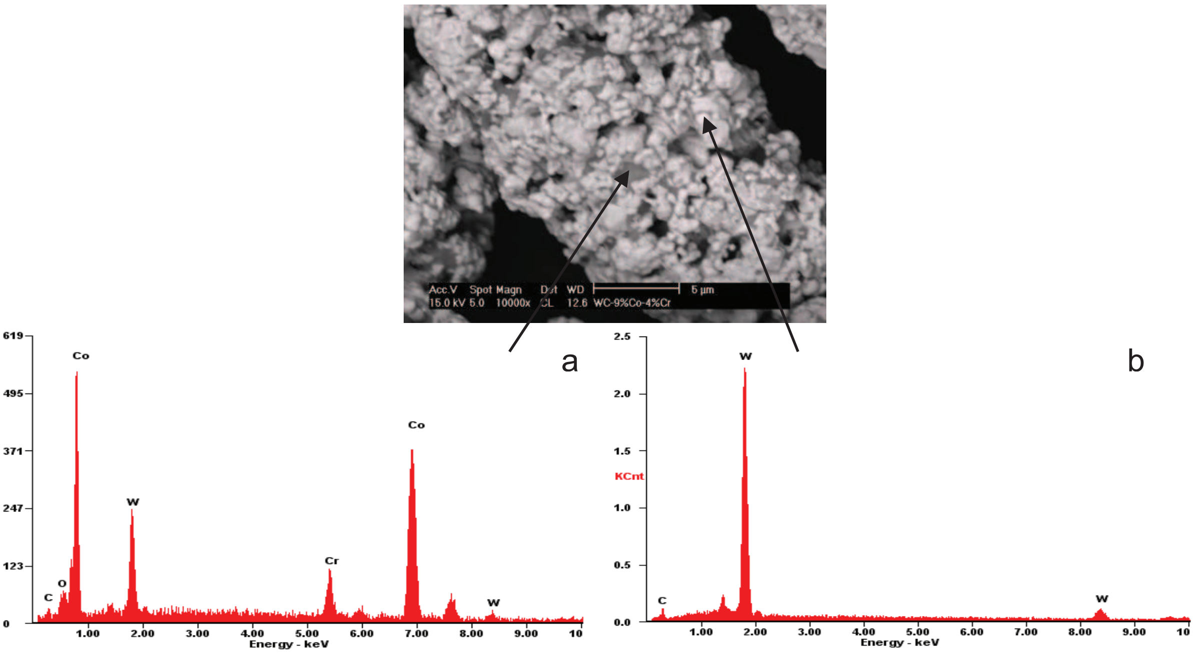

Figure 1. SEM image and EDS of WC-9Co-4Cr particle showing the (a) Co-Cr binder and (b) WC.

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 while 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 as well as hardness testing. XRD of the coated surface was performed on a PW1710 Philips diffractometer, using monochromatic Cu Kα radiation at 40 kV and 20 mA while the phases were identified using X pert High Score Plus software. The microstructures and the distribution of hard phases were examined using a field emission scanning electron microscope (FESEM) equipped with energy dispersive spectrometer (EDS). Microhardness profiles of the cross section from the coated zone to the matrix at 100 µm intervals were measured using an EMCO TEST Durascan microhardness tester at a load of 100 g.

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. No pores and cracks were present from the SEM images. It could be seen that undissolved WC cermets are present at the top surface of the coatings and this vary for all the coatings with specimen 1 alloyed at laser power of 2.0 kW and scan speed of 0.6 m/min having most of such undissolved carbides . This could be attributed to the volume of carbides injected and the coated surface exposure to the atmosphere. At low scan speed, more carbides are injected into the melt pool and due to high cooling rate, the carbides at the top solidifies before being dissolved. High wettability of WC and strong marangoni convection also aids the uniform distribution of dissolved carbides in the melt pool and segregation of the undissolved carbides at the coating surface as can be seen in figure 2.

Melting, dissolution and resolidification of WC took place to form WC, W_2C, Co_6W_6C and $M_{23}C_6$ (M=Fe, Cr, W) as indicated in the XRD analysis in figure 3. The EDS point analysis in figure 4 also confirms the presence of W, C, Co, Cr elements in the matrix.

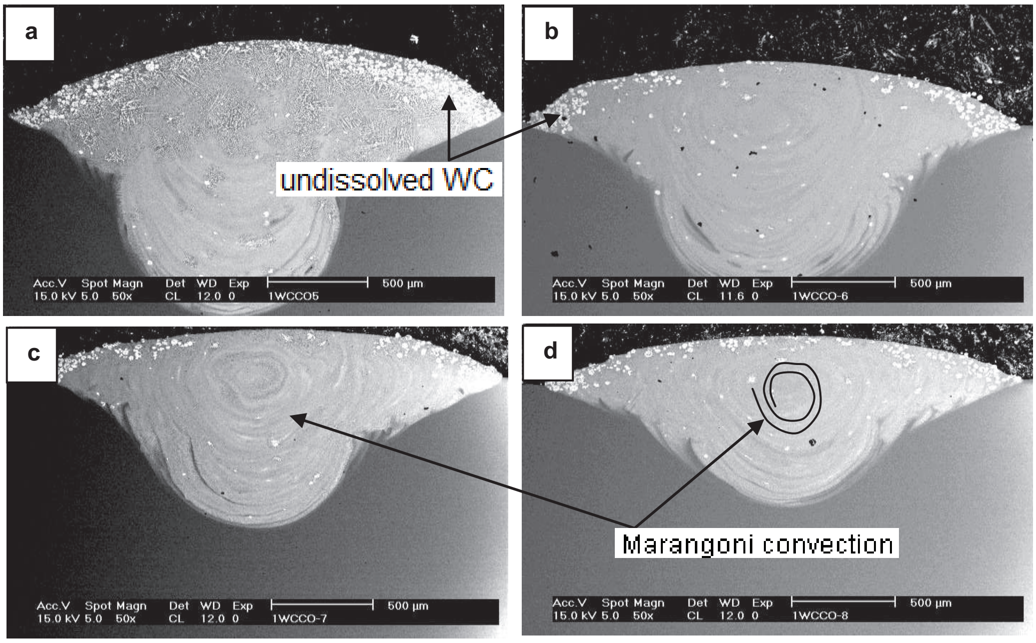

Figure 2. SEM micrograph of 304L stainless steel alloyed with WC-Co-Cr at laser power of 2.0 kW and scanning speed of (a) 0.6, (b) 0.8 (c) 1.0 and (d) 1.2 m/min

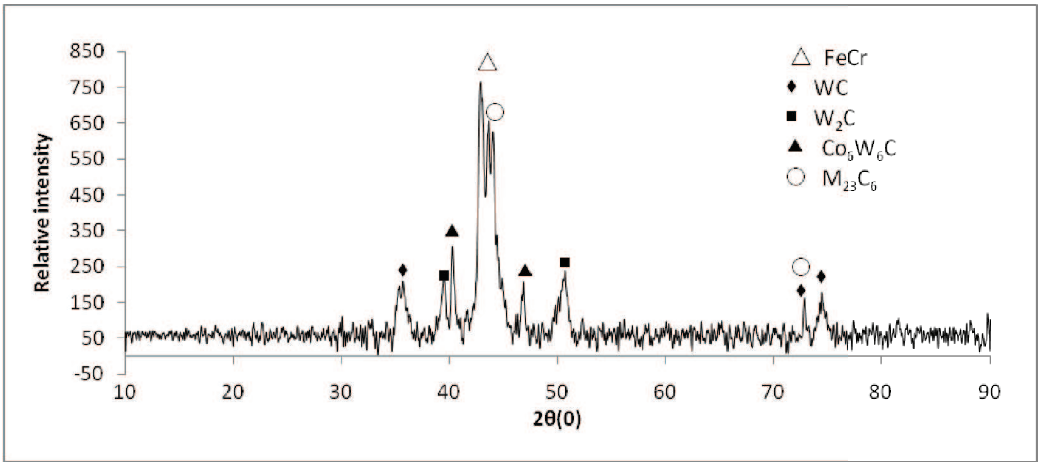

Figure 3. XRD analysis of specimen 1at laser power of 2.0 kW and scan speed of 0.6 m/min.

Microhardness measurement was performed on the cross section of the specimens from the coated layer to the matrix as shown in figure 5a. Specimen 1 at laser power of 2.0 kW and scan speed of 0.6 m/min gave the highest hardness of 1331 $Hv_{0.1}$. The coating thicknesses for the specimens were found to be approximately 1750, 1260, 1140 and 1055 µm respectively as shown in figure 5b. The variation in hardness and 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.

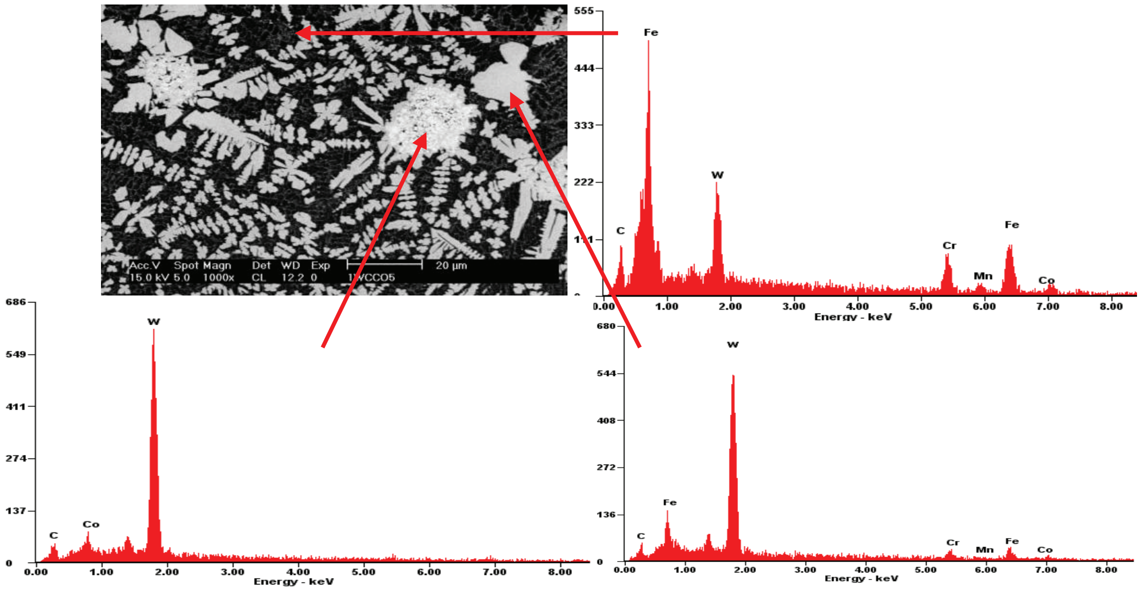

Figure 4. SEM image and EDS point analysis at laser power of 2.0 kW and scan speed of 0.6 m/min

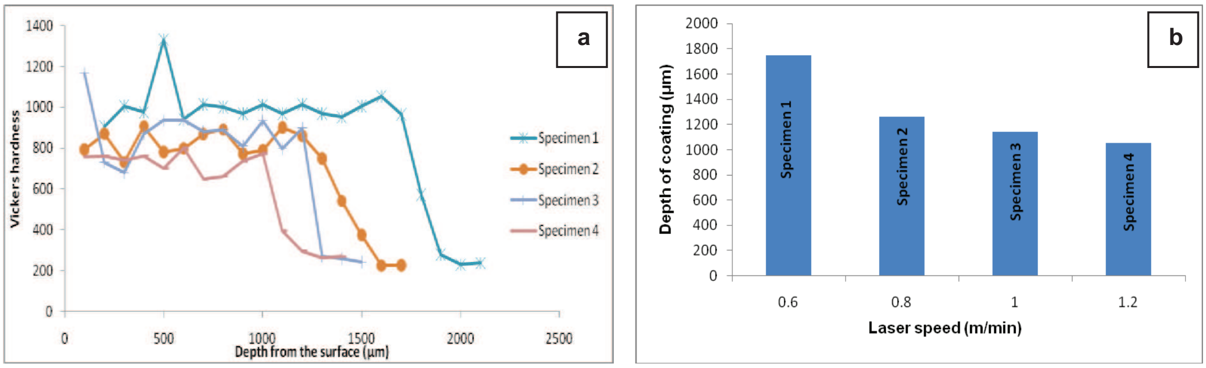

Figure 5. (a) Microhardness profiles of the alloyed layers and (b) Depth of coated zone as a function of laser speed.

4. Conclusion

It has been shown that 304L ASS matrix composite can be prepared by laser surface alloying without pores and cracks. Laser surface alloying with WC cermet powder result in an increase in hardness of 304L ASS. At laser power of 2.0 kW and scan speed of 0.6 m/min, hardness value was about 5 times that of the matrix. This is attributed to the formation of hard phases such as WC, W_2C and Co_6W_6C.

Acknowledgements

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