DEFECTS CHARACTERIZATION OF CHROMIUM CARBIDE OVERLAY'S DEPOSITED BY SUBMERGED ARC WELDING*

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Abstract

Welded deposited chromium carbide overlay's has been widely used in various branches of welding overlay's industry related to wear. Characterization techniques are an important tool in the development of chromium carbide overlays resistant to wear, enabling the identification of phases, constituents and defects. In this work one used optical microscopy, scanning electron microscopy and energy dispersive spectroscopy on chromium carbide overlay's deposited by submerged arc welding process. The characterization techniques identified precisely the elements of the overlay's enabling point of the main cause of the observed defects such as cracks, porosity and clusters of particles known in the industry as " rice crispy" .
Keywords: Chromium carbide overlay's; Submerged Arc ; Characterization ; Welding defects.

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1 INTRODUCTION

Chromium carbides (CCO's) consist primarily of iron, chromium, carbon and small amounts of manganese, silicon , molybdenum , nickel and copper . The resulting microstructure consists of M_7C_3 carbides and Austenite [1].
Chromium carbides may be deposited by various welding processes, but submerged arc is the welding process most commonly used due to its operational simpilicity and productivity [2].
There are, however, a number of problems associated with weldiing that make decrease the designed properties. The features and defects that may contribute to the loss of properties comprise the following: Gas porosity, Oxide inclusions and oxide filming. Solidification (hot) cracking or hot tearing [3].
In CCO's microstructure is common to observe cracks, porosity, granular agglomerates of particles called in the industrial environment of "Rice Krispies", these structures, despite its recurrent occurrence in industrial processes are barely mentioned in the literature.
In this work characterization techniques such as visual inspection, optical microscopy, scanning electron Microscopy and energy dispersive spectroscopy on industrial CCO's deposited on plain steel plates by submerged arc welding process.
The employed techniques precisely identified the coating microstructure enabling point out the probable causes of defects such as porosity, cracks and "rice crispy ", originating from the manufacturing processes.

2 MATERIALS AND METHODOLOGY

The CCO analyzed in this study was obtained by submerged arc welding (SAW) process using low carbon steel 32mm wire diameter (Lincoln L- 61). The difference in between the process employed for CCO's and conventional process consists in adding alloying powders composed by chemical elements such as chromium, carbon, manganese and molybdenum in front of the torch, see (figure 1). The employed flux (OK Flux 10.71), which protects the weld pool and balance the composition of the ovelay, must have the ability to solidify after the weld bead. The flux density should be smaller than the weld pool enabling it flotation in the molten material and later on be separated easily from the CCO after complete solidification of the weld bead.
The weld bead is applied using a weaving technique with 44.4 mm oscillation amplitude and 6.35 mm overlap on each pass. The industrial CCO industrial welding parameters are shown in (Table 1).

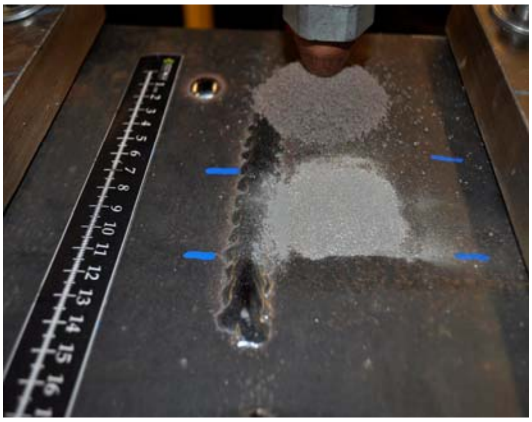

Figure 1. Addition of alloying elements on CCO 's submerged arc welding

The analyzed CCO was deposited by SAW industrial process on carbon steel plate 8620 (2440mmX6100mmX6,35mm) with 6.35 mm designed thickness. After the deposition process the material is cooled to ambient air, being available without post welding heat treatment.
The sample was withdrawn from a CCO plate (406.4mmX406.4mmX12.7mm) and cutted (15mmX5mmX12.7mm) transversely to welding speed direction, see (figure 2). The sample was grinded and polished according to standardized sample preparation procedures for metallographic observation. The material was analyzed with naked eye, optical microscope and scanning electron microscope (SEM) coupled with energy dispersive spectrometer (EDS).

Table 1. Industrial SAW parameters for CCO's

Welding parameters	***Values***
Contact tip to workpiece distance	31.75 mm
Travel speed	245 mm/min
Oscillation speed	3.17 m/min
Wire feed speed	1.63 m/min
Voltage	33 V
Powder to wire ratio	1.75

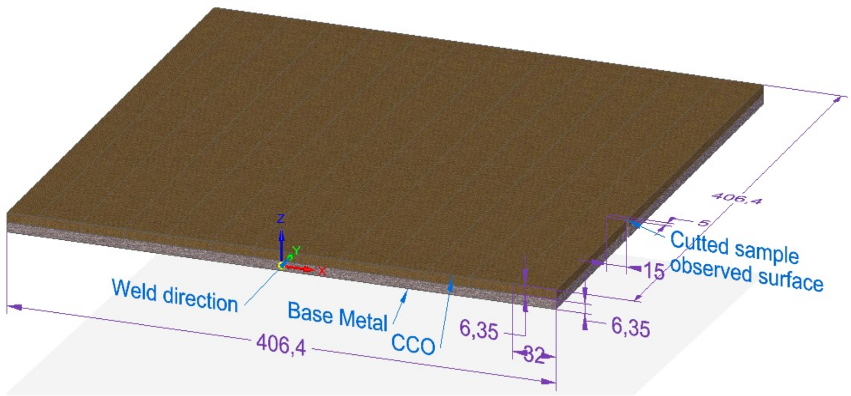

Figure 2. Sketch showing CCO plate, location and dimensions of the sample

3 RESULTS AND DISCUSSION

3.1 Visual Inspection

Industrially CCO’s has a relatively smooth surface with shallow recesses along the overlap in between the weld beads, see (figure 3), despite presenting transverse cracks to welding direction.
Cracks in CCO1s are caused due to thermo mechanical loads inherent to the solidification process. Base metal bends applying tensile stresses in the CCO bead after the contraction caused by solidification. The CCO’s are sold with these cracks as it is believed that the main role of the CCO is the wear resistance and for industry this defects are not an important issue.

ISSN 1516-392X

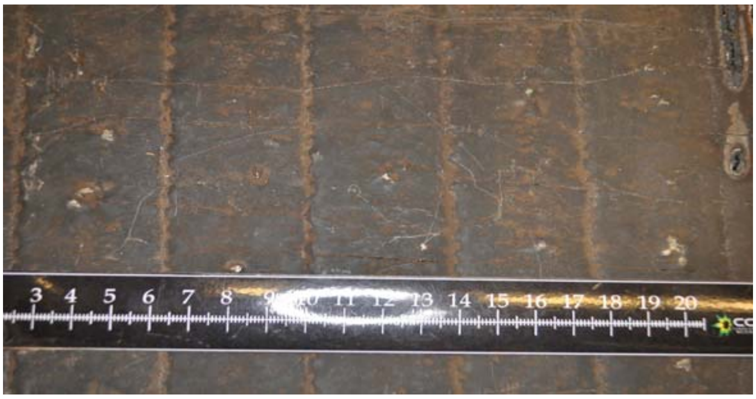

Figure 3. Surface top view of industrial SAW CCO sample showing cracks and bead overlap recess

3.2 Optical Micoscopy and Scanning Electron Microscopy

The sample was analyzed by optical microscopy where the overall CCO micrography was build through a mosaic view. The entire cross-sectional microstructure can be observed from the base metal , mixed zone, intermediate zone until it reaches the top zone of the sample, see (figure 4).

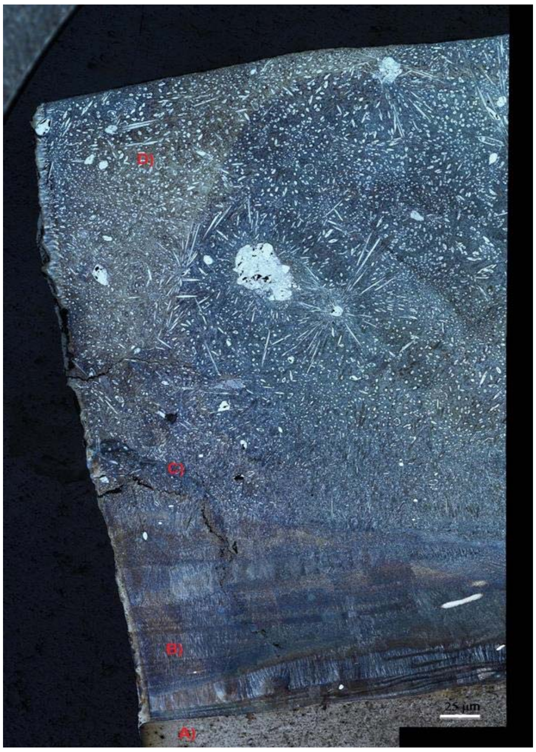

Figure 4. Mosaic microstructure 50X, etchant 20 ml H_2O, 10 ml HCl , 30ml HNO_3 and 5 g $FeCl_3$. A) Base metal B) Mixed zone C) Intermediate Zone D) CCO Top zone.

SEM at lower magnitude was also used to obtain an overview of the microstructure, besides the austenitic matrix were observed, eutectic carbides (lamellar shape), primary carbides (hexagonal shape) and defects such as " rice crispy " , porosities and cracks, see (figure 5).

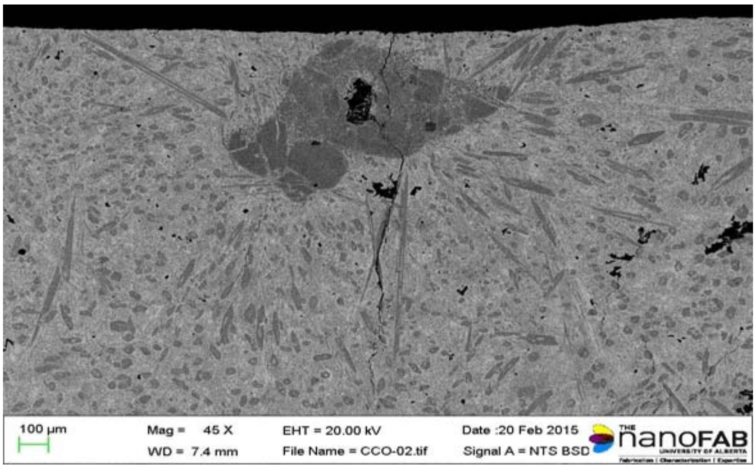

Figure 5. Backscattered SEM showing the "rice crispy" with a porosity in the center and a crack passing through.

There is a higher incidence of "rice crispy" on top of CCO, see (figure 4), porosity was also observed within the " rice crispy" , see (figure 5). This may be related to gas entrapment in "rice crispy" resulting from the alloying powders manufacturing process. The crack initiated on top of CCO and propagating through the surface porosity in "rice crispy", proceeding toward the base metal, see (figure 5).

3.3 Energy Dispersive Spectroscopy

Energy dispersive spectroscopy technique was used in order to identify the chemical elements in between the CCO matrix and "rice crispy" see (figure 6).

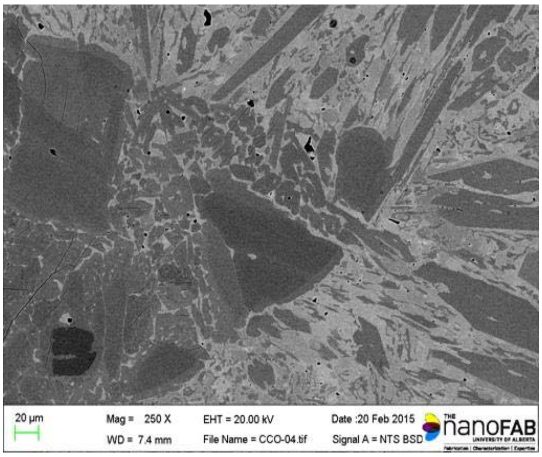

Figure 6. Backscattered SEM showing the area of the "rice crispy" selected for EDS analysis

The EDS results for iron and chromium, shown in (Figure 7) demonstrated that the " rice crispy" is composed mainly of chromium surrounded by the iron matrix. Chromium content in the "rice crispy" is similar to the surrounding primary hexagonal carbides. One observed a high chromium content in small particles of hexagonal shape at the end of Chromium carbide. Cobalt is dissolved mainly in the iron matrix, see (Figure 8). Manganese has been found mainly in the carbide and "rice crispy" see (figure 9). Manganese is added to increase hardenability.

ISSN 1516-392X

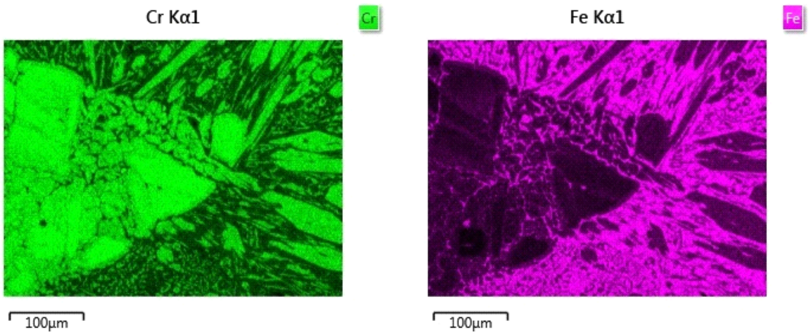

Figure 7. EDS mapping results in between the "rice crispy" and the CCO matrix for Iron and Chromium

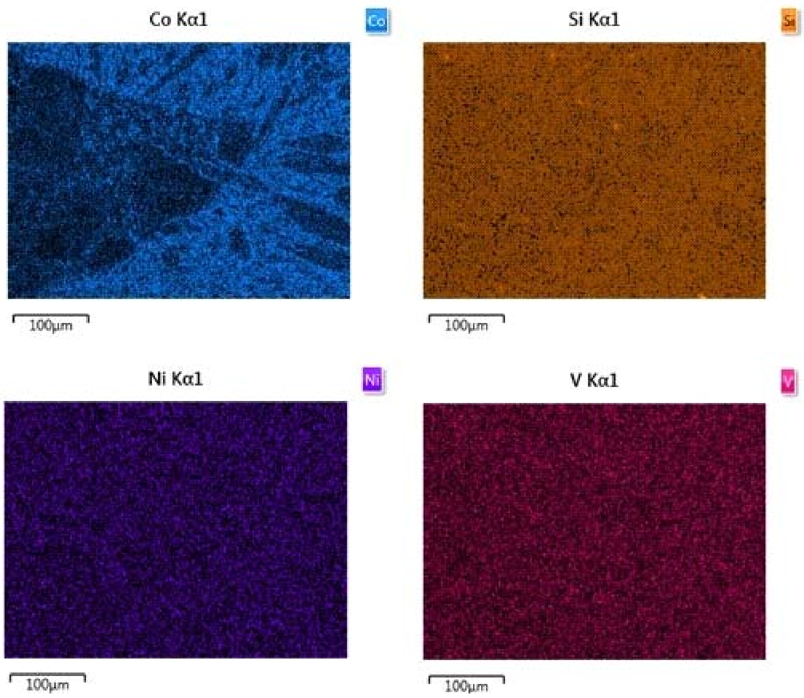

Figure 8. EDS mapping results in between the "rice crispy" and the CCO matrix for Cobalt, Silicon, Nickel and Vanadium

ISSN 1516-392X

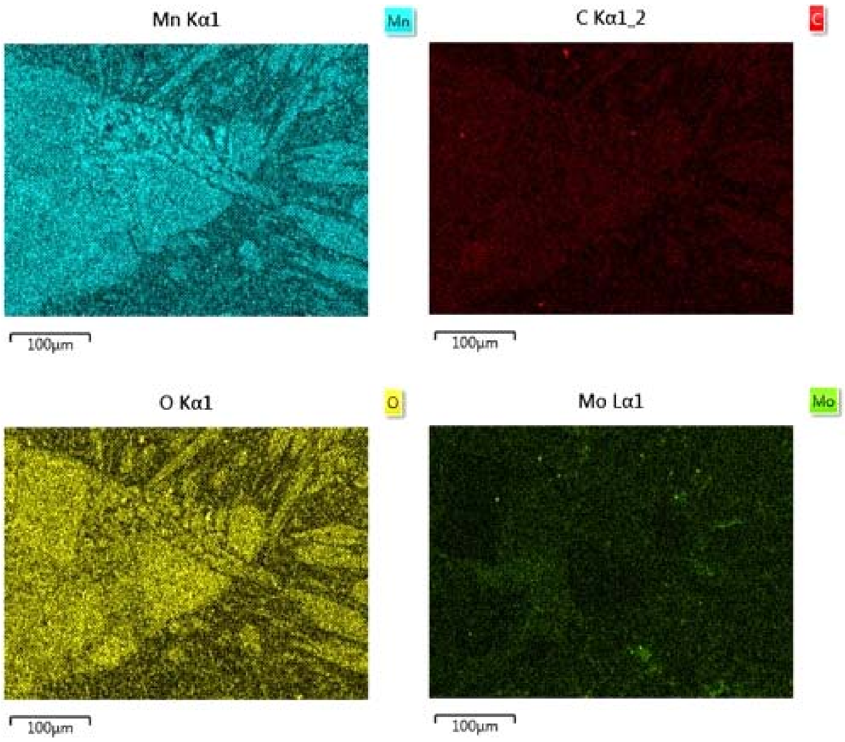

Figure 9. EDS mapping results in between the "rice crispy" and the CCO matrix for Manganese, Carbon, Oxygen and Molybdenum

4 CONCLUSION

CCO's showed many defects such as cracks, porosities and clusters of particles known in the industry as "rice crispy". Cracks begin on top of CCO and propagating towards the base metal. Cracks propagate through “rice crispy” due their major weakness probably by its fragile carbide constitution and the presence of stress raiser like porosities. The "rice crispy" occurs mainly at the intermediate zone and top zone due to bubbles entrapped inside which could be inherent to the powder manufacturing process which reduces its density. "rice crispy" are probably undissolved carbides derived from the alloying powders rich in chromium used in CCO’s submerged arc welding.

Acknowledgments

This study has been supported by Canadian Centre For Welding and Joining (CCWJ) and Coordination for the Improvement of Higher Education Personnel (CAPES).

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