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# Structure and mechanical properties of stainless steel coatings deposited by arc wire spraying.

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**ABSTRACT —** In this work, two different stainless steel namely (X10CrNi 18-8 and X30Cr13) were sprayed onto a steel blasted substrate E335 using arc spraying process. The chemical composition of the phases that are present in the coatings were characterized by using an X-ray diffraction (XRD), Measurements of Vickers hardness, under a load of 300g, were also performed on the coatings. The tribological tests were carried out on a type of tribometer pin-on-disc at differents loads (5N, 10, 15, 20 and 30N) for sliding duration of 30 minutes in order to determine the rate wear under two different sliding velocities. The results showed It was found that the solid solution (bcc) (Fe, Cr, Ni), while chrome carbide Cr7C3 and $Ni_3C$ phases are formed for X10CrNi18-8. However X30Cr13 revealed the presence of body-centered cubic (bcc) (Fe, Cr) structure that corresponds to the solid solution and the formation of only carbides of chrome such as CCr and $C_7Cr_3$, dealing with the large statistical variations of composition. We also note the presence of a large fraction of oxides type $Fe_3O_4$.The Vickers microhardness of X30Cr13 is the higher due to the emergence of Oxides which is not appears in another stainless coating X10CrNi18-8. The wear resistance of the two stainless coatings X10CrNi18-8 and X30Cr13 is affected by sliding velocities under different applied loads. The stainless coating X10CrNi18-8 exhibits remarkably bad wear rate than X30Cr13 coating.

***Keywords**: Coatings, Stainless steel, Wear.*

## I. Introduction

The Stainless steel coatings are widely used for improving corrosion resistance on the surface of steels because of their low cost and high efficiency. Arc spraying process (ASP) and wire-arc sprayed stainless steel coatings contain relatively high amounts of porosity and oxides since the particles heated to high temperature readily react with oxygen in the atmosphere. The oxidation of alloying elements such as chromium results in the formation of chromium-depleted areas, and therefore, impairs the mechanics and corrosion resistance of the coatings employed in various corrosive environments [1–5]. The arc spraying process (ASP) is a thermal spray process, in which heating and melting occur when two oppositely charged wires, comprising the spray material, are fed together in such a manner that a controlled arc occurs at their intersection. Once struck, the arc continuously melts the wires, and compressed air blown directly behind the point of contact, atomizes and projects the molten droplets, which deforms on impact with the work piece and adhere to form a coating. Adhesion on the other hand is heavily dependent on the surface preparation i.e. if the surface is adequately prepared it improves the adhesion between the coating material and the substrate. Solvent cleaning or grit blasting

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normally achieves adequate surface preparation. The electric arc-spraying process can be used to effectively deposit surface coatings that have superior hardness, corrosion resistance, and wear resistance [6-10]. In addition to these advantages, the spray parameters (voltage, current, air pressure and spray distance) of the electric arc spray process can be optimized for specific application, for example, wear [11-14]

In this paper, this investigation aims to focus on aspects related to the structure, and mechanical properties of two different stainless steel of nuance X10CrNi 18-8 and X30Cr13 deposited on a low carbon steel E335 by the arc spraying process (ASP) technique. The structure of different coatings was analyzed using an X-ray diffraction (XRD). Measurements of Vickers hardness, under a load of 300g, were also performed on the coatings. The tribological tests were carried out on a type of tribometer pin-on-disc at different loads for sliding time of 30 minutes in order to determine the rate wear under two different sliding velocities

## II. EXPERIMENTAL PROCEDURE

### II.1 Preparation of coatings

The substrate used in the present investigation was an E335 steel with the following nominal chemical composition (wt %) obtained by using analysis X-rays fluorescence (Fe: balance, Cu: 0.2 wt%, C: 0.1-0.15 wt%, Ni: < 0.05 wt%, Mn: 0.2-0.25 wt%). Before the coating process, the surface of the substrate was grit blasted with corundum particles of 99,50 wt % purity and 0,5 mm mean particle size, using an air of 0,4MPa, an incidence angle of 90° and a gun-to-substrate distance of 150 mm. The surface was then cleaned and degreased using acetone with an ultrasonic bath. The grit blasted substrates were coated with two different wire form of 1,6 mm diameter of stainless steel. This wire was continuously melts, and compressed air blown directly behind the point of contact, atomizes and projects the molten droplets. The coatings subsequently deposited had average thickness 0.8 to 1 mm. The chemical composition of coatings is shown in table 2.

The wire were sprayed onto grit blasted substrates using an APS technique (model Arc Spray 234) and the input parameters are 4,5 bar oxygen pressure,voltage35 V, current 100 A, deposited weight 6 kg/h, covered area 8 m2/h/0.1 mm, rate of traverse 2 m/min, Spraying distance 140 mm, wires diameter 1.6 mm.

Table 2. Chemical composition of materials used

| **Materials %** | **C** | **Cr** | **Mo** | **Fe** | **Ni** |
|---|---|---|---|---|---|
| **X10CrNi18-8** | <0,1 | 18 | <0,5 | Bal | 8 |
| **X30Cr13** | 0,3<br>à 0,4 | 12<br>à 14 | 0,25<br>à 0,35 | Bal | <0,5 |

### II.2 Coating characterization

The surface of samples was ground using SiC paper with grit sizes and finally polished with alumina. The phases present in the coatings was identified using X-ray diffraction. The X-rays diffraction patterns were recorded at room temperature with a X'PERT PRO MRD diffractometer of PANalytical equipped with a Cu-anode X-ray tube and a curved graphite monochromator in the diffracted beam set of Cu-Kα radiation which includes the Kα1 and Kα2 wavelengths. The strong presence of defects in these materials creates a significant background noise; to improve counting statistics and increase the peak/background ratio, an acquisition time of 40 s was used per angular step of 0.04° over the 30° – 120° (2θ) range. The identification of the crystal phases present in the coatings was performed using X'PertHighScore software supported with the ICDD-PDF2 database.

### II.3 Hardness Investigation

The microhardness of the coatings (Vickers scale) was measured using a Vickers hardness tester B 3212001 type Zwick. The measurements were carriedout on the cross-sections of the coatings. A load of 300 g was selected for the average values ofthe coatings. The given microhardness value was the average of 10 measurements.

### II.3 Wear Resistance Performance

The abrasive wear test was carried out a pin-on-disc. The specimens dimension was cylindrical pin of 10mm diameter and 15mm length. The pin-on-disc contact tests were performed under different loads (5, 10, 15, 20 and 30 N) with a siding distance of 900 m and 1800m, sliding speed of 0.5 m/s and 1m/s. A sintered steel disc 100Cr6 was employed as the counter body with a new disc being used for each test. In order to study the wear behaviour of coatings in severe conditions, the tests were carried out without any lubrification. The wears experienced by the samples during the tests were determined by weighting each sample before and after the test. The weight loss suffered by the pins was measured using electronic weighing balance having an accuracy ± 0.01 mg. The wear rateis calculated usingthe following equation:

$$K_v = \frac{\Delta m}{N_c} \qquad (1)$$

Kv: wear rate

Δm: weight loss.

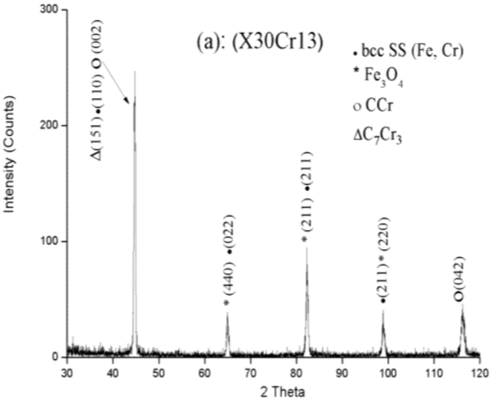
NC: number of cycles.

## III. RESULTS AND DISCUSSION

### III.1 Structural examination

The XRD patterns of both coatings stainless steel are shown in Figure 1.

Figure 1-a shows the diffraction X-ray patterns of the coating X10CrNi18-8. It proves the presence of a body-centered cubic (bcc) (Fe, Cr, Ni) structure with a lattice parameter of 2,8673 A° that corresponds to the solid solution (JCPDS n° 00-035-1375). The carbides $Cr_7C_3$ (JCPDS n° 036-1482) and Ni3C (JCPDS n° 01-072-1467) phases are formed by the reaction between carbon and nickel or chrome when the temperature exceeds 1200°C [14, 15]. The temperature of the molten particle is highly greater than 1200 °C during arc spraying process. However, large amounts of part of chrome reacted with oxygen during the coating process and formed $Cr_3O$ oxides.



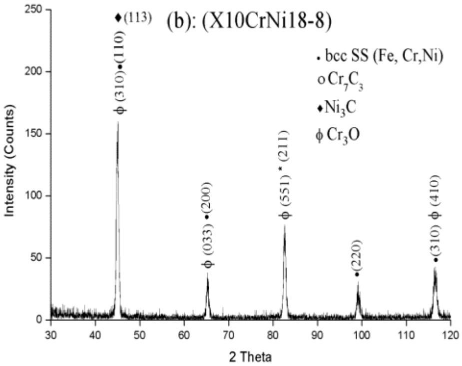


Fig. 1 XRD pattern of coatings: a) X30Cr13 b) X10CrNi18-8.

The diffraction X-ray pattern of the coating X30Cr13 (figure 2b) revealed the presence of body-centered cubic (bcc) (Fe, Cr) structure with a lattice parameter of 2,8673 A° that corresponds to the solid solution and the formation of only carbides of chrome such as CCr and C7Cr3, dealing with the large statistical variations of composition. The formation of these carbides is made possible as a result of the larger content of carbon. We also note the presence of a large fraction of oxides type Fe3O4.

### III.2 Structural examination

Results of microhardness measurements from the substrate to the coating surface at the longitudinal section are depicted in Fig.2. The average microhardness of the substrate, coating X10CrNi18-8 and coating X30Cr13 is 201 HV0.3, 380 HV0.3 and 560 HV0.3, respectively. The high microhardness in the X30Cr13, compared to the coating X10CrNi18-8, is attributed to their different chemical composition. Indeed, the coating X30Cr13 contains only chrome and carbone elements, which can form strong carbides such as Cr7C3 and CCr that led to increase the strength of stainless steel coatings. In Contrary, the decreased microhardness of X10CrNi18-8 is due to the presence of carbide Ni3C thus decreasing a residually stress in this coating. The reason of higher microhardness in the interface of coating X30Cr13 is due to the emergence of carbides. However, the highest microhardness in the surface of this coating may be due to the appearance of oxides caused by contacting with air.

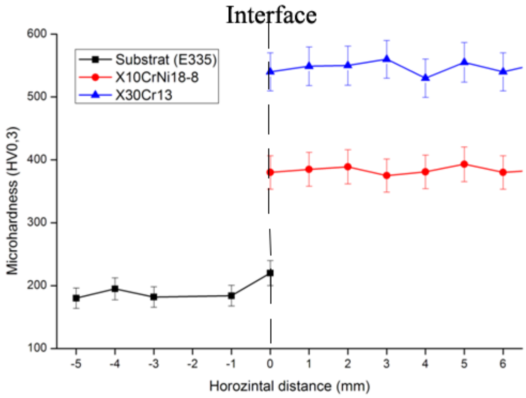
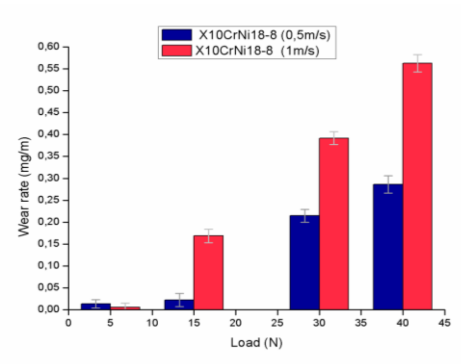


Fig. 2 Microhardness profile from substrate to coating surface.

### III.3 Structural examination

The two coatings were performed on pin-on-disc tribometer with two sliding velocities 0,5 m/s and 1m/s under different loads in order to determinate the wear rate. The figure 6 shows the variation of the wear rate of the two coatings in function load.



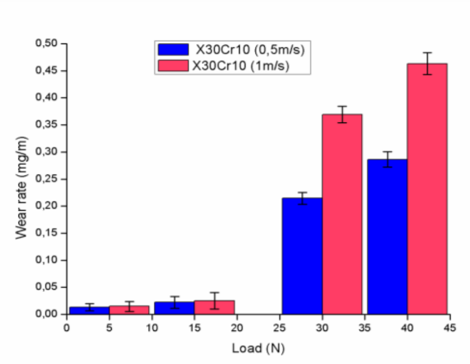


Fig. 3 Evolution of the wear rate of the coatings as function load.

Fig. 3 shows the wear rates of coatings X10CrNi18-8 and X30Cr13 as function of applied load. It presents similar wear resistances increases of both sliding velocity and applied load lead to higher wear rates. Under high load, when the sliding velocity is increased from 0.5 to 1 m/s, the wear rate is sharply increased. The wear rate becomes much higher only with increasing the sliding velocity.

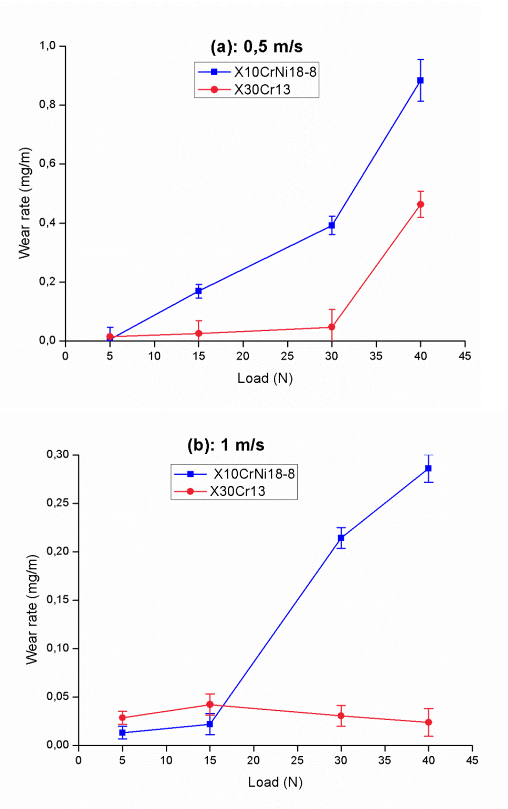


Fig. 4. Evolution of the wear rate of the coatings as function load.

Fig.4 shows a comparing the wear resistance of the two coatings X10CrNi18-8 and X30Cr13 versus the abrasive load. The wear rate of X30Cr13 is linearly increased according to the sliding load and appears to be very slightely. However, the stainless coating X10CrNi18-8 exhibits remarkably bad wear rate than X30Cr13 coating. It can be due to the of presence of carbides chrome such as CCr and $C_7Cr_3$ and the presence of a large fraction of oxides type $Fe_3O_4$.

## V. CONCLUSIONS.

The present research paper has summarized the structural and mechanical properties of coatings fabricated by stainless steel X30Cr13 and X10CrNi18-8 by using the Arc Spray Process technique. It can be concluded as follows:

- The diffraction X-ray patterns of the coating X10CrNi18-8 proves the presence of a solid solution body-centered cubic (bcc) (Fe, Cr, Ni) and carbides $Cr_7C_3$ and Ni3C. whereas, the diffraction X-ray pattern of the coating X30Cr13 revealed the presence of cubic body-centered solid solution (bcc) (Fe, Cr), the formation of only carbides of chrome, and the presence of a large fraction of oxides type $Fe_3O_4$.

- X30Cr13 coating presents much higher Vickers hardeness than X10CrNi18-8. The higher microhardness in the interface of coating X30Cr13 is due to the emergence of carbides.

- X30Cr13 coating presents much higher wear resistances than X10CrNi18-8.

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