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Effect of WC Concentration on Abrasive Wear Properties of the Thermally Sprayed WC -Ni Coatings

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Abstract- In this work the effects of WC concentration on abrasive wear behavior by thermally sprayed WC coating was evaluated using three body abrasive wear tester. A different combination of WC and NI coatings were deposited on steel substrates by flame spraying using powder with different WC concentrations (0 %, 12.5 %, 25 %, and 50 %). Flame torch was used for heating and coating of process. Microstructure properties of coated samples were evaluated using optical microscope and wear testing, were performed on the samples.. Experimental results were compared to determine which coating shows the best quality in terms of the wear resistance. It was found that wear resistance is strongly depend on percentage of WC up to a certain level of mixing after that wear resistance will start decreasing.

Index Terms- flame spraying, wear resistance, Ni and WC.

I. INTRODUCTION

Powder coatings deposited by flam spraying techniques are applicable in many areas of industry. These coatings increase the life of machine parts because of its exclusive properties. There is a wide range of the powders available to use for synthesis of these coating. These powders differ in their chemical composition, grain size, production method and, because of those differences, in the field of application [1]. By applying coatings on a surface one can reach different goals: to increase hardness, wear resistance, fracture toughness, corrosion resistance. Depending on the possible goals mentioned above, the proper powder material should be chosen for the coating. One of the widely used materials is tungsten carbide –Nickel Wc-Ni. The WC/Ni is notable for its high hardness and toughness. WC-Ni powder particle consists of the hard tungsten carbide grain imbedded in tough cobalt matrix. Another material used to produce these alloy Ni-Wc. Actual composition of this material may vary due to the field of application, but the properties are mainly influenced by hard boride, carbide and silicide phases [2, 3]. By adding WC/Ni powder to NiCrBSi on we can change properties of the produced coating. Physical and mechanical properties in such a case depend on the proportions of those materials in the coating [4, 5].

In present study, the flame spraying technique was used for the formation of the coating where flame is created by combustion of fuel gas and oxygen mixture in the gas chamber of the thermal spraying gun. Powder is injected into the flame using inert compressed gas. It melts in the flame and is transferred in this state to the substrate where it cools down. This treatment is called re melting and is performed using flame torch or high temperature furnace [5, 6].

The goal of this study was to evaluate the influence of WC/Co concentration in NiCrBSi-WC/Co powder on coatings physical and mechanical properties after it is sprayed and re melted. Concentration varied from 0 % of WC/Co in the mixture to 50 % WC/Co.

II. EXPERIMENTAL

2.1. Formation of Coatings Using Flame Spraying

WC based 4070 powder and NI based 1060were used for the flame spraying. Chemical composition of these powders is shown in Table 1 and Table 2. Here and further in the paper, composition of the materials is expressed in mass concentration percentage. The flame spraying equipment consisted of flame spraying gun, powder feeder and gas supply system. Compressed nitrogen was used as carrier gas for powder transportation from feeder to gun and acetylene with oxygen were used to form flame. Specimens were mounted on a cylinder shaped holder and rotated around axis at about 200 rpm. Coatings were deposited on (25.4×06×76.2) mm size steel substrates. Coating thickness was 2 mm. All coatings were re melted using acetylene-oxygen flame torch. Fusing and cooling was performed in air.

Table1. Chemical composition of Ni based powder in wt (%)

C	B	Si	Fe	Cr	Ni	WC
0.75	3.1	4.3	3.7	14.8	Balance.	-

Table 2. Chemical composition of Wc based powder in wt (%)

C	B	Si	Fe	Cr	Ni	WC
4.0	-	-	-	-	-	Balance

2.2 Methodology of Sample Analysis

Prepared specimens were cut to several pieces perpendicular to the coating using band saw. Microstructure analysis, micro-hardness tests, phase composition evaluation was performed. For the microstructure analysis, samples were mounted and polished according to the metallographic procedures. Etching was performed in 15 ml water, 30 ml HCl, 15 ml HNO_3 and 15 ml acetic acid. The samples were analyzed using optical microscope and SEM. Porosity was determined from the micrographs using image analysis programs

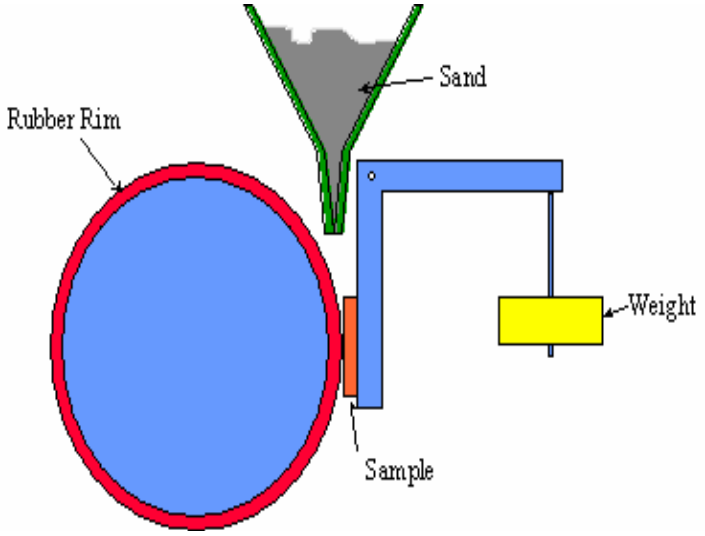
The characteristic of flame spraying is mention at Table 3

Characteristics	**Flame spraying**
GAS temperature (^{0}C)	3000
Spray rate (Kg/h)	1-9
Particle velocity (M/S)	>50
Bond strength (mpa)	7.83
Coating thickness (mm)	0.1-3
Hardness (HRc)	20-60

2.3 Wear Testing

Three- body abrasive wear test was performed for each of the coatings. The principal scheme of the three body abrasive wear test machine used in this experiment. Disk was rotating at 200 rpm. The applied load was 98, 196amd 294 N loads. Mass loss was measured and paper was changed every 200 revolutions. Maximum revolutions were made on every sample, which corresponds to sliding distance of 5124 m. To avoid surface roughness influence on the results, the samples were grounded before wear test. Mass loss was evaluated using a weighing machine.

Fig. no. 1



III. SELECTION OF LOAD

Table.4

SI.NO	**LOAD N**
1	**98 N**
2	**196 N**
3	**294 N**

3.2. SELECTION OF TREATMENT

Table.5

SI.NO	**TREATMENT**
1	**1060**
2	**1060+12.5%**
3	**1060+25%**
4	**1060+50%**

IV. RESULTS & DISCUSSION

4.1 MICROSTRUCTURE

The spray coated specimens were prepared for metallographic examination by conventional grinding and polishing techniques. The polished and etched surfaces were examined using an optical microscope

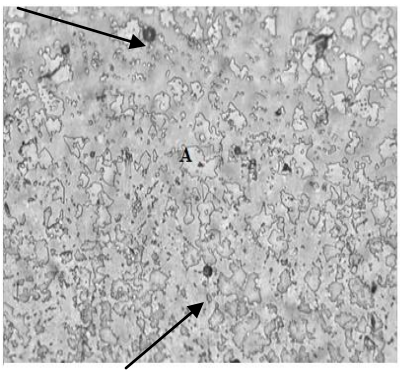


Figure: 2 optical microstructure of 1060 alloy with 12.5 wt % WC coating

[A: Matrix, Single arrow; Porosity]

Figure.2 shows the microstructure features of 1060 alloy. The morphology of alloy shows that the structure is uniform with an occasional presence of micro porosity, then porosity may be due to the entrapment of gases during coating process.

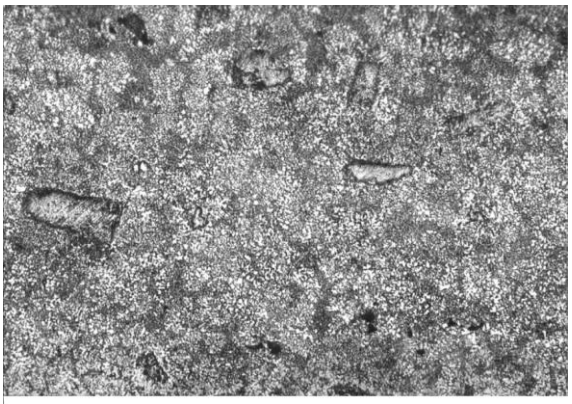


Figure: 3 optical microstructure of 1060 alloy with 12.5 wt % WC coating
[A: WC particle, B: matrix]

Fig.3 shows the microstructure features of 1060 alloy with 12.5 wt % WC. The morphology of coating shows that the structure is uniform distribution in the matrix alloy and good interfacial bonding. The porosity /cracks were not observed in all the composites of (1060+12.5 wt% WC) in the matrix alloy with good interfacial bonding.

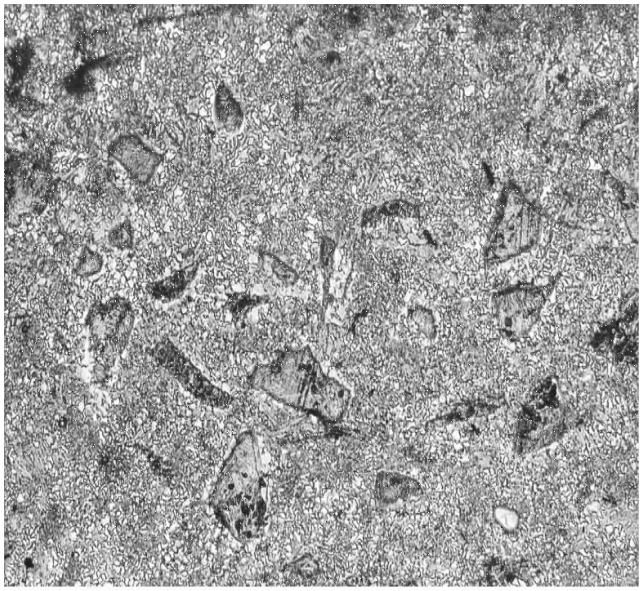


Figure 4: optical microstructure of 1060 alloy with 25 wt % WC coating.
[A; WC particles, B; Matrix]

Figure 4; shows the microstructure feature of 1060 alloy with 25 wt % WC coated alloy .The morphology of coating shows that uniform distribution in the matrix alloy and good interfacial bonding. The porosity /cracks were not observed in all the composites of (1060+25 wt% WC) in the matrix alloy with good interfacial bonding.

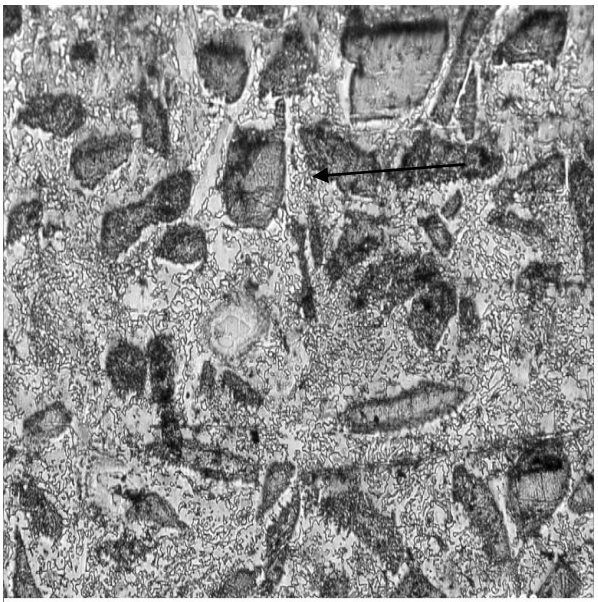


Figure: 5 optical microstructure of 1060 alloy with 50 wt% WC
[A: WC particle, B, Matrix, Single Arrow; Interface]

Figure.5 shows the microstructure features of 1060 alloy with 50 wt % WC coated alloy .The morphology of coating shows uniform distribution in the matrix alloy and good

interfacial bonding. The porosity /cracks were not observed in the composites of (1060+50 wt % WC) in the matrix alloy with good interfacial bonding.

4.2- Wear interpretation of micro structure

The higher mass wear in selected alloys as a result of microstructure could be attributed to absorption tungsten carbide, poor crack resistance due to porosity, carbide size and its distribution etc.

4.3 WEAR RESISTANCE

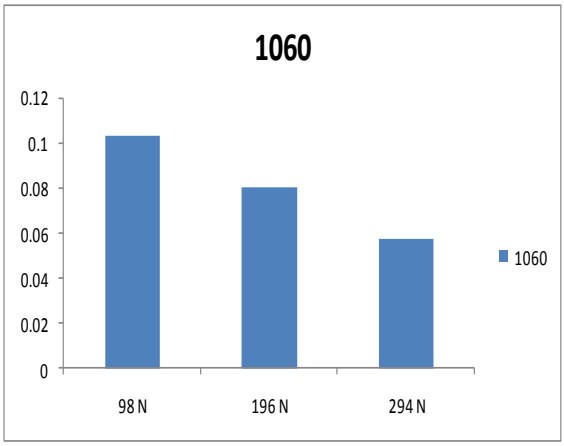


Fig. 6

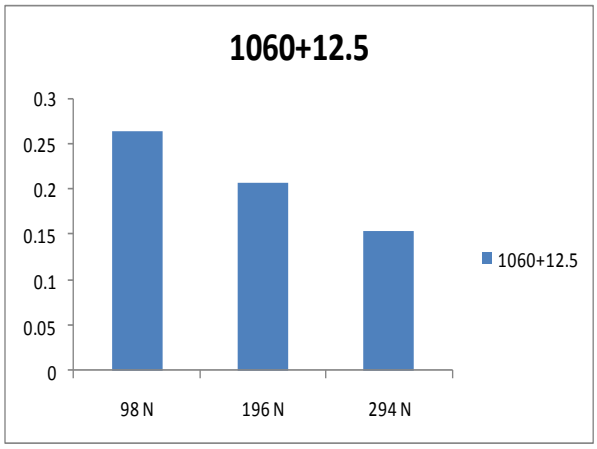


Fig.7

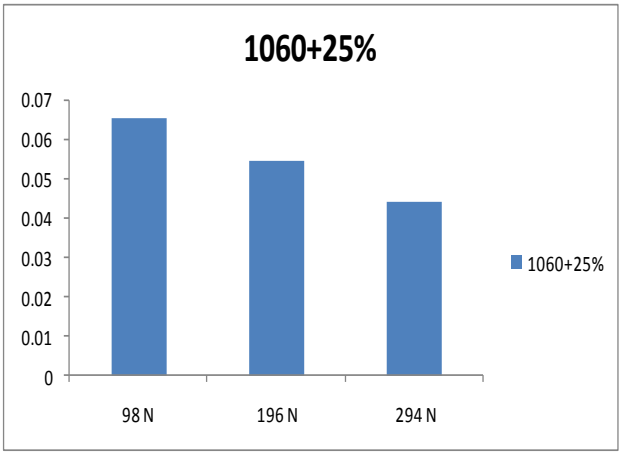


Fig.8

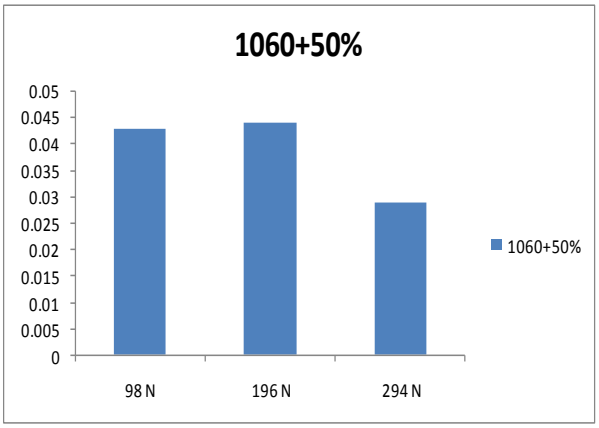


Fig.9

4.4 Measurement of wear

The samples were cleaned with acetone and weighed up to the accuracy of 0.0001 mg using DELMER electronic balance prior to and after each test. The wear was calculated from the weight loss measurement and expressed in the terms of weight loss per unit sliding distance i.e. in mg/m.Mass loss for each set of experiment is calculated using the following formula

$$M = (W_i - W_f)$$

Where, W_i is the initial weight of specimen before the test has been started, W_f is the final weight of specimen after the wear test has been completed . For each experiment, weight loss is calculated up to the wheel travel distance of 5124 meters. Values after the each 144 meters wheel travel distance were taken for the calculation and analysis purposes.

4.5 Mechanism of mass wear under influence of wheel travel

This could be attributed to wear mechanisms taking place in this scenario. Initially, the higher mass wear could be due to the formation of oxides which are loosely held in the matrix. These particles will be detached from the specimen easier than other zones of the coating, increasing consequently showing higher at one beginning the mass wear. Then the loss of material from the wear surface of the coating take place primarily by removal of soft matrix material followed by fragmentation of hard carbide particles After removal of these oxide, the matrix and inter metallic bonds the development and propagation of the cracks resulting in to higher wear resistance.

4.6 Reason for mass wear behavior of selected alloys at different loads

It is evident from previous section that higher mass wear with highest drop were observed at higher loads in alloys with higher WC%. This could be attributed to absorption WC in the main matrix. The WC absorb was appropriate up to 12.5% on words it reduce and result into higher mass wear.

V. CONCLUSION

To compare the all selected alloy higher wear resistance in this chapter, the conclusions drawn from the tests have been discussed

1. The 1060+12.5% was found to have significantly minimum mean weight loss (9.24 mg).
2. The mean weight loss was found to be maximum (26.84 mg) at 294 N load.
3. The weight fraction of WC in the selected powder as play vital role at 12.5% wt, minimum values of mass wear were observed at all loading. The value of mass wear below and above 12.5% was higher .
4. The minimum values of mass wear are followed are 1060+12.5% WC, 1060, 1060+25% WC, and 1060+50% WC alloy.

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