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Effect of Spray Stand-off on Hardness of Thermally Sprayed Coatings

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Abstract**—**The mechanical and tribological properties in WC-Co coatings are strongly affected by hardness and elasticity specifications. The results revealed the effect of spraying distance on microhardness and elasticity modulus of coatings. The metallurgical studies have been made on coated samples using optical microscopy, scanning electron microscopy (SEM).

Keywords**—**HVOF, Micro-indentation, Thermal spray, WC-Co.

I. INTRODUCTION

OVER the last years, the substitution of hard chromium plating has been promoted due to the new legislation concerned to hazardous wastes of Galvanic Industries. Thermal spraying with high velocity oxygen fuel (HVOF) has been very successful in spraying wear resistant WC–Co coatings with higher density, superior bond strengths and less decarburization than many other thermal spray processes. This is attributed mainly to its high particle impact velocities and relatively low peak particle temperatures [1]. As a class of hard composite materials of great technological importance, WC–Co powder cemented carbides are widely used by various thermal spray processes to deposit protective coatings in a large variety of applications [2].

Mechanical behavior of thermally sprayed coatings such as thermal and peening stresses, adhesive and cohesive stresses as well as fatigue behavior is strongly affected by hardness and elasticity specifications. The elasticity modulus of WC-Co coatings is strongly affected by nature of selected thermal spraying technique and method of measurement. So researchers have reported different values for hardness and elasticity modulus [3]-[7].

In this study the effect of spraying distance as an important parameter on microhardness of HVOF thermal spraying coating using Knoop microindentation has been investigated. The metallurgical and Tribological studies were made coated samples using optical microscopy, scanning electron microscopy (SEM), X-ray diffraction.

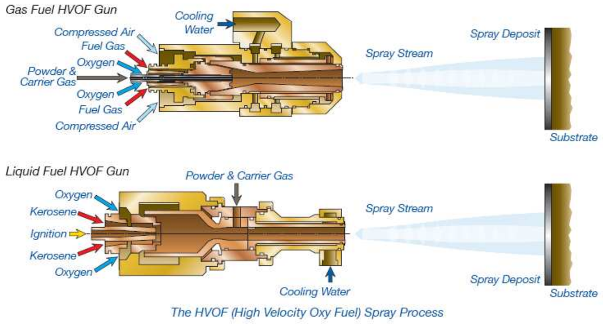

Fig. 1 High velocity oxy-Fuel thermal spraying

II. EXPERIMENTAL PROCIDURE

The coating was deposited industrially by employing a HVOF gun type Metjet III onto AISI 1045 steel substrate samples of 10×10×4 mm^3. The WC-12Co powder used had a particle size between ~15 and 40μm. The spray parameters were according to Table1. Before deposition the substrate was grit blasted with alumina particles with 16μm mesh. Coatings with thickness of 300±30 μm were thermally sprayed. The microhardness and elasticity modulus of coating were measured according to ASTME384-10 in cross section of coating-substrate.

TABLE I
SPRAYING PARAMETERS IN THIS STUDY

Parameter	Quantity
Fuel rate (ml/min)	250
Oxygen rate (l/min)	830
Spray distance (mm)	240,340,380,440
Spray angle (deg)	90

Scanning electron microscopy (SEM) and image analysis were performed to evaluate the crystalline structure phases, morphological and porous structure of the WC-12Co powder and its coating respectively.

III. RESULT AND DISCUSSION

A. Microstructure

Fig. 2 illustrates the Scanning Electron Microscopy (SEM) morphology of agglomerated WC-12Co powder. The shape of powder particle is spherical in range of 12-40 μm. the spherical particles require less kinetic energy for good adhesion on the substrate. Fig. 3 illustrates a general view of the coating after metallographic preparation. The WC-12Co HVOF thermally sprayed coating appear to be quiet dense.

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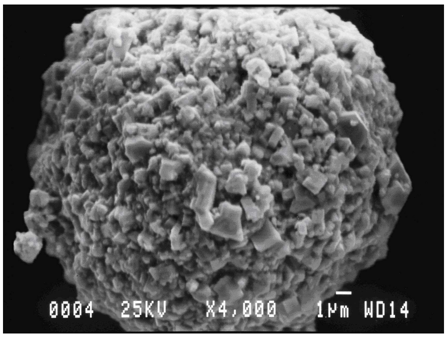

Fig. 2 powder Morphology by SEM micrograph

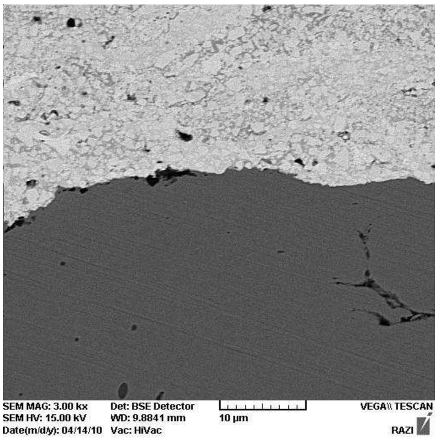

Fig. 3 SEM micrograph of substrate-coating interface

B. *Microindentation*

Elastic modulus (E) and Knoop hardness (HK) were evaluated on the polished cross sections of the WC–Co coatings. The distance between two indentations was not less than three times the minor diagonal to prevent stress field effects from nearby indentations. The elastic modulus test was based on the measurement of elastic recovery of the in-surface dimensions of Knoop indentation [8]–[10]. The formula for deter mining E is [11]:

$$E = \frac{\alpha HK}{(b/a)-(b'/a')} \tag{1}$$

where α is a constant having a value of 0.45, HK is the Knoop hardness value, a' and b' are the lengths of the major and minor diagonals of the Knoop indentation, which were accurately measured by OM (Optical Microscopy, and b/a = 1/7.11 is the ratio of the Knoop indenter dimension. In this work the elastic modulus and Knoop hardness were evaluated respectively, when the major diagonal of the Knoop indenter positioned perpendicular and parallel to the coating surface According to point mentioned in [7]. This is because the elastic modulus is sensitive to the minor diagonal of the indentation according to Eq. (1), and the Knoop hardness is sensitive to the major diagonal of the indentation. A load of 200 g and a dwelling time of 10 s were applied for all the measurements. The values of elastic modulus and microhardness presented are the average of 10 measurements made on the identical polished cross section of each sample. Fig. 4 and Fig.5 illustrate the variation of microhardness and young's modulus versus the spray distance respectively. As can be seen, decreasing the spray distance leads to increasing the hardness of WC-Co coatings. This is described due to formation of W_2C in coating when the impact temperature is the highest in closest standoff. In addition to process parameters such as spray parameters, the elasticity modulus is related to nature of employed process and method of measurement. A comparison of other's works and the result of this work are concluded in table II.

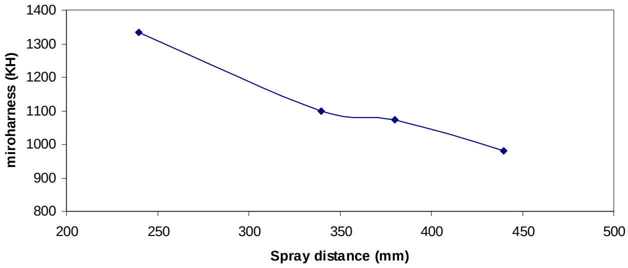

Fig. 4 Measured microhardness of WC-12Co coating in N=200g in different spray distance

TABLE II
MICROHARDNESS IN DIFFERENT SPRAY DISTANCE

Distance(mm)	Microhardness(HV)
240	1333
340	1098
380	1074
440	982

TABLE III
COMPARISON OF OTHER'S WORKS AND THIS WORK

Results	Quantity
J.Pina[3]	1050
Roy[4]	928
T.Gang[7]	1030
This study(d= 340mm)	1098

IV. CONCLUSION

The microhardness and elasticity modulus of WC-12Co coating deposited by HVOF thermally spraying process have been investigated. The microindentation and metallurgical analyses were employed for this purpose. The results showed the decreasing of the hardness and elasticity modulus by increasing the spray distance.

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