Effect of Spray Stand-off on Microhardness and Elasticity Modulus of Thermally Sprayed Coatings

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Abstract: The application of thermally sprayed coatings on metallic parts has been widely accepted as a solution to improve their mechanical and tribological properties**.** These properties are strongly affected by hardness and elasticity specifications. In this study the effect of spraying distance as an important parameter on microhardness and elasticity modulus of HVOF thermal spraying coating using Knoop microindentation have been investigated. 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 and scanning electron microscopy (SEM).

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1. 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 spray is a promising method replacing the hazardous chrome plating in the finishing industry. This method has demonstrated to have superior wear and fatigue properties when compared to hard chromium using cermets e.g. tungsten carbide-cobalt (WC-Co). High velocity oxy fuel (HVOF) coatings have exhibited wear resistant WC-Co coating with high density; superior bond strength and less decarburization than many other thermal spray methods. This is attributed to its high particle impact velocities and relative low peak particle temperature [1], [2].

In this study the effect of spraying distance as an important parameter on microhardness and elasticity modulus of HVOF thermal spraying coating using Knoop microindentation has been investigated. Morphological and crystallographical studies were conducted using optical microscopy, scanning electron microscopy (SEM) and X-ray diffraction respectively to evaluate the powder and coating characteristics.

2. Material and Methods

Agglomerated WC-12 Co powder was coated industrially on AISI1045 steel substrate samples of 10×10×4 mm^3 using high velocity oxy fuel method by employing a HVOF gun type Metjet III. 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 using knoop microindentation according to ASTM ASTME384-10 in cross section of coating-substrate. Scanning electron microscopy (SEM) and image analysis were performed to evaluate the morphological and porous structure of the WC-12Co powder and its coating respectively.

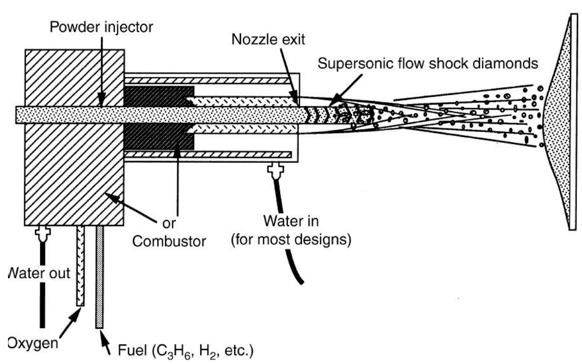

Fig.1: High velocity oxy-Fuel thermal spraying

Table 1: Spraying parameters in this study

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

3. Results and discussion

A. microstructure

Fig. 2 illustrates the Scanning Electron Microscopy (SEM) morphology of agglomerated WC-12Co powder. Each particle consists of nano size tungsten carbides embedded in cobalt matrix.

The resultant shape of agglomerated and sintered 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 HVOF coating after metallographic preparation. The WC-12Co HVOF thermally sprayed coating appear to be quiet dense and with uniform distribution of carbides in Co matrix.

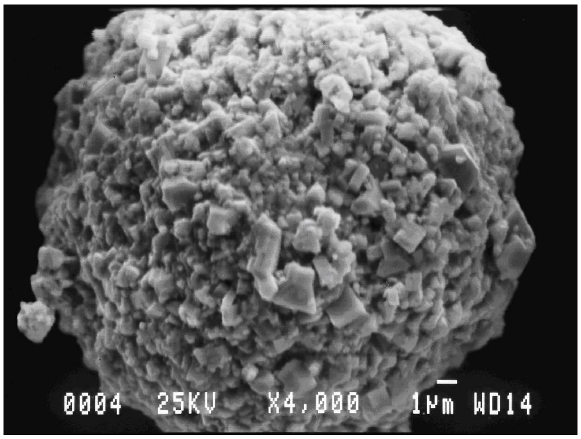

Fig.2: powder Morphology by SEM micrograph

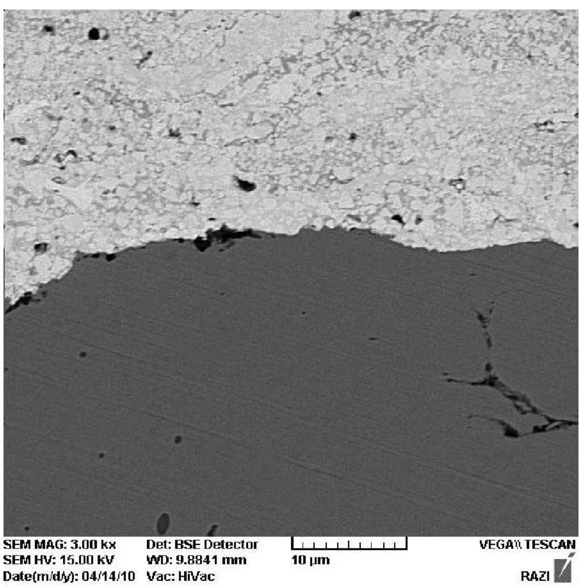

Fig.3: SEM micrograph of substrate-coating interface

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]:

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

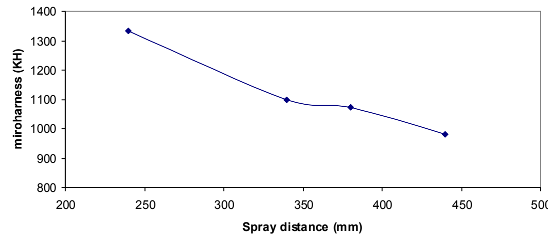

Fig.4: Measured microhardness of WC-12Co coating in N=200g in different spray distance

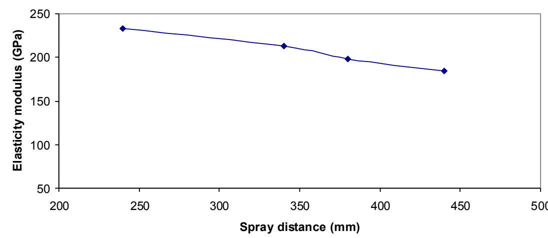

Fig.5: Measured elasticity modulus of WC-12Co in N=200g in different spray distance

Table2: Comparison of other's works and the result of this work

	Microhardness	Elasticity modulus (GPa)
J.Pina [3]	1050	175
Roy [4]	928	170
Kim [5]	-	181-331
Toparli [6]	-	398
T.Gang [7]	1030	238
This study (d= 340mm)	1098	213

where 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 notes 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, increasing the spray distance leads to decreasing the hardness and elasticity modulus of WC-Co coatings. The reduction of microhardness may be related to residual stress that is related to particle velocity. 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 table3.

4. 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 mechanical properties such as microhardness and elasticity modulus by increasing the spray distance.

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