International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:8, No:3, 2014

# The Effect Particle Velocity on the Thickness of Thermally Sprayed Coatings

M. Jalali Azizpour, H. Mohammadi Majd

***Abstract*****—**In this paper, the effect of WC-12Co particle velocity in HVOF thermal spraying process on the coating thickness has been studied. The statistical results show that the spray distance and oxygen-to-fuel ratio are more effective factors on particle characterization and thickness of HVOF thermal spraying coatings. Spray Watch diagnostic system, scanning electron microscopy (SEM), X-ray diffraction and thickness measuring system were used for this purpose.

***Keywords*****—**Grinding, HVOF, Thermal spray, WC-Co.

## I. Introduction

BOND strength, stress distribution, compressive nature of residual stresses as well as the fatigue behavior of the coatings could be considered as the outlined features of HVOF coatings [1], [2] (Fig. 1). Mechanical, metallurgical and tribological properties of the coatings strongly influenced by the independent (primary)variables (the spray distance, oxygen to fuel ratio, powder feed rate, etc.) and related (secondary) parameters such as velocity and temperature of particles at the impact [3]-[5]. The ultrasonic particles velocities in HVOF thermal spraying process can produce compressive residual stresses hence improve mechanical properties such as fatigue life and bonding strength [6]. Due to high cost WC-Co powder, it is important for industry to achieve deposition efficiency more than 60 percent.

In this study the effect of HVOF thermal spraying process parameters on particle velocity and thickness of WC-12Co coating on AISI1045 substrate has been investigated. Effect of the most important parameters such as spraying distance, the oxygen to fuel ratio, feed rate and gun speed was analyzed statistically using Taguchi approach. The standard array L9 was used to design of the experiments.

## II. Experimental Procedure

In this study, the WC-12Co powder (HC Starck Co.) with particle size of 15-45μm was used. Widely used AISI1045 steel was considered for substrate. Spray Watch diagnostic system (Oseir, Finland) was used for monitoring the particles velocity. The Taguchi approach was used for design of experiments based on the average of outputs. Applying the Taguchi method can be considered as a low-cost method to optimize the thermal spraying processes. Scanning electron microscopy (SEM) was used to determine the morphology and microstructure of powder as well as thickness of the coating.

M. Jalali Azizpour (correspond author) and H. Mohammadi Majd are with PTRI of ACECR. (phone:+986113358552, e-mail: mjalali@iauahvaz.ac.ir).

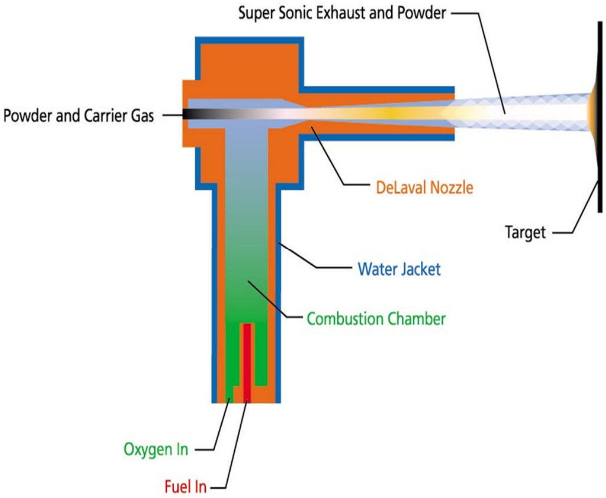


Fig. 1 HVOF thermal spraying gun

## III. Results and Discussion

### A. Morphological Characterization

Fig. 2 illustrates the Scanning Electron Microscopy (SEM) morphology of agglomerated- sintered WC-12Co powder in 500x. As observed the particles are spherical and uniformly distributed (15-45μm) with high porosity. Fig. 3 illustrates a general view of the coating after metallographic preparation. The WC-12Co HVOF thermally sprayed coating appear to be quiet dense.

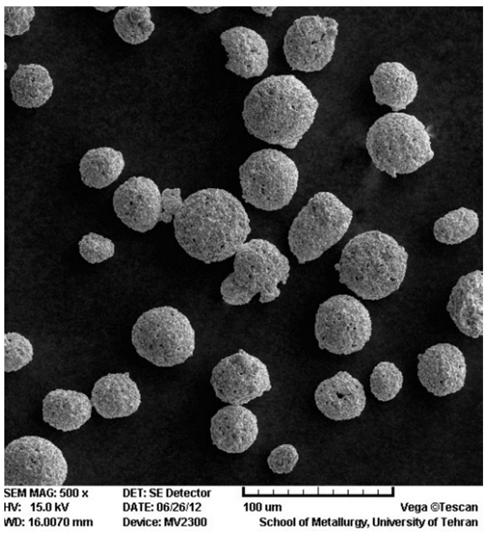


Fig. 2 Particle morphology in 500x magnification

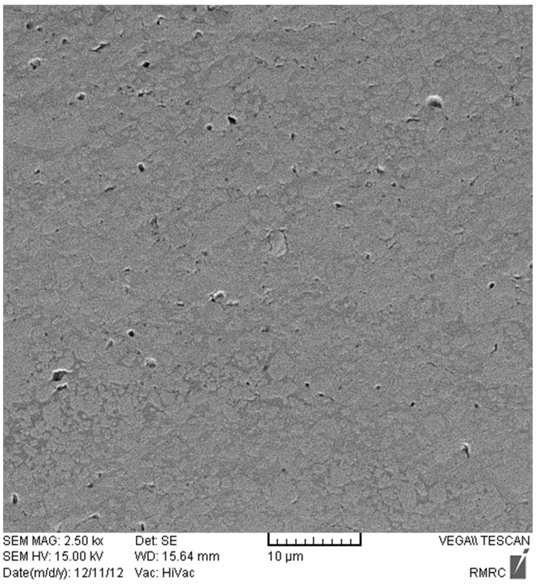


Fig. 3 SEM micrograph of WC-12Co coating

### *B. Design of Experiments*

In this study the Taguchi fractional factorial method was used for finding the optimum conditions of coating thickness and evaluation the response of the optimum conditions. For factors and selected levels in this study, Taguchi approach suggests L9 standard array. Taguchi orthogonal array and the average of coating thickness in each condition are tabulated in Table I. The particles have different kinetic energy in impact due to particle size distribution in feedstock. Particle size distribution shows that 50% of the particles have diameter of 34.3µm. The impact velocity distribution of more than 3000 monitored particles in this study is illustrated in Fig. 5. The quality characterization was selected to be the bigger the better.

For the bigger the better quality characterization the optimum thickness of 345.5µm was obtained for the A3/B3/C2/D1 test condition. As the A3/B3/C2/D1 condition is existed in the used standard array, validation test was not conducted for this purpose. The response in A1/B2/C1/D1 test condition shows that the coating thickness is V=355µm which has good agreement with optimum result of Taguchi approach.

TABLE I
TAGUCHI ARRAY FOR DOE

| Test No. | A | B | C | D | Thickness, µm |
|---|---|---|---|---|---|
| E1 | 1 | 1 | 1 | 1 | 195 |
| E2 | 1 | 2 | 2 | 2 | 236.25 |
| E3 | 1 | 3 | 1 | 1 | 212.5 |
| E4 | 2 | 1 | 2 | 1 | 288.75 |
| E5 | 2 | 2 | 1 | 1 | 257.5 |
| E6 | 2 | 3 | 1 | 2 | 298 |
| E7 | 3 | 1 | 1 | 2 | 269.5 |
| E8 | 3 | 2 | 1 | 1 | 289 |
| E9 | 3 | 3 | 2 | 1 | 355 |

The average effect of spray parameter on the obtained coating thickness is shown in Figs. 4 through 6. The particle velocities were measured in previous study [7]. The particle velocity decreased by increasing the spray distance but it can be seen that the thickness increased by spray distance. This should be in result of decreasing in splash ratio. In case of oxygen to fuel ratio the increasing trend of particle velocity is not permanent and decreases in level 3 (F/O=4.3). But the increasing trend is permanent.

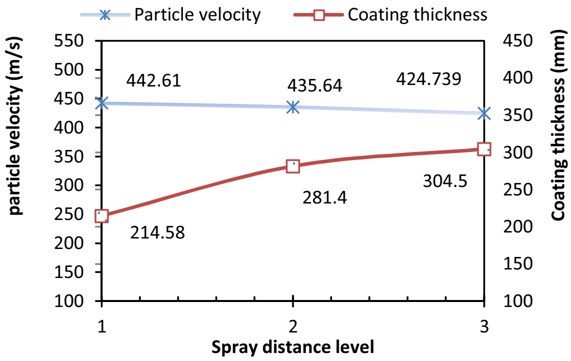


Fig. 4 Effect of SD on velocity and thickness

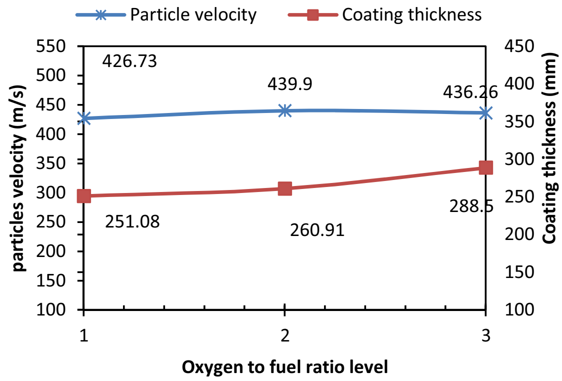


Fig. 5 Effect of O/F ratio on velocity and thickness

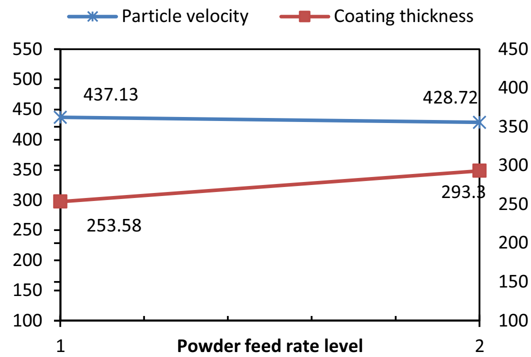


Fig. 6 Effect of feed rate on velocity and thickness

## IV. Conclusion

In this study the effect of thermal spraying process parameters on particle characteristics and thickness of WC-12Co coating on AISI1045 substrate has been investigated. A summary of conclusions is as follows:

- The response in A1/B2/C1/D1 test condition shows that the coating thickness is V=355µm which has good agreement with optimum result of Taguchi approach.
- Spray distance has the strongest influence on the thickness with near to 70 percent participation.

## References

[1] M. Heydarzadeh Sohi, F. Ghadami, Comparative Tribological Study of Air Plasma Sprayed WC–12%Co Coating versus Conventional Hard Chromium Electrodeposit, Tribology International, 2009.
[2] Y.Y. Santana, Characterization and Residual Stresses of WC–Co Thermally Sprayed Coatings, Surface & Coatings Technology 202 (2008) 4560–4565
[3] C. Lyphout, Residual Stresses Distribution through Thick HVOF Sprayed Inconel 718 Coatings, Journal of Thermal Spray Technology, Volume 17(5-6) Mid-December 2008—915.
[4] Stewart DA, Shipway PH, McCartney DG. Microstructural Evolution in Thermally Sprayed WC–Co Coatings Acta Mater 2000; 48:1593–604.
[5] Yang Q, Senda T, Ohmori A. Effect of carbide grain size on Microstructure and Sliding Wear Behavior of HVOF-sprayed WC–12% Co Coatings. Wear 2003; 254: 23–34.
[6] T.C. Totemeier, Residual Stress Determination in Thermally Sprayed Coatings—A Comparison of Curvature Models and X-Ray Techniques, Surface & Coatings Technology 200 (2006) 3955 – 3962.
[7] M. Jalali Azizpour, S. Nourouzi, The Effect of Spray Parameters on the WC-12Co Particles Velocity, Iranian Journal of surface science, vol16(45-53)2013.