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Characterization of Various Substrates Coated With Different Coating Powders by Thermal Spray Processes: A Brief Review

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Abstract—*In this paper we studied the most commonly done characterization of the coated substrates. To improve the surface properties (hardness, roughness, porosity, and wear resistance etc.) of the substrate coating is done. Characterization is used to study the effect of coating powders on the substrate surface properties. Characterization is done using Optical microscope, X-Ray Diffraction, Scanning Electron Microscope (SEM), Energy Dispersive X-Ray Analysis (EDXA) and Analytical Transmission Electron Microscopy (AEM). In this paper we present few such researches and studies which help us to know the effect of characterization on the substrate surface properties*

1. INTRODUCTION

Coatings on the metal products are very common these days; it is done either for protective or for both protective and decorative purposes. Coatings or finishing are used for the purpose of surface protection, corrosion resistance, and providing of a hard surface [1]. Most commonly used method for coating is thermal spray coating. Some the commonly used thermal spray coating are Plasma spraying, Detonation spraying, Wire arc spraying, Flame spraying, High velocity oxy-fuel coating spraying (HVOF), etc. After coating is completed many test are done to check the improvement in surface properties. Some of the commonly conducted tests on coated substrate are abrasive wear test, sliding wear test and many more. These tests are done for the substrate but for the coating characterization is done. Characterization is used to study the effect of coating powders on the substrate surface properties. In this paper we present few such researches and studies which help us to know the effect of characterization on the substrate surface properties.

2. CHARACTERIZATION

It is the process by which a structure and properties of a material are explored, examined and measured. It is a elementary process in the field of materials science, without which engineering materials could not be discovered scientifically. Some of the Characterization techniques are:

Optical microscope,
X-Ray Diffraction,
Scanning Electron Microscope (SEM),
Energy Dispersive X-Ray Analysis (EDXA),
Analytical Transmission Electron Microscopy (AEM), and etc.

3. STUDIES RELATED TO PROCESS PARAMETERS OF DETONATION GUN COATINGS FOR VARIOUS MATERIALS

P. Saravanan et al [2]**,** compared the characteristics of Al_2O_3 coatings deposited using Atmospheric Plasma Spraying and D-gun spaying by using Taguchi experimental design. For every particular coating considerable level of the process parameter is selected and to understand the magnitude of influence that each variable had on coating properties the experimental data was fed to multiple regression analysis and analysis of variance (ANOVA) [3]. Results obtain for APS and D-gun sprayed Al_2O_3 coatings were

a. ANOVA calculation confirms that the spray distance was the most dominant factor in reducing the surface roughness.
b. Lower porosity is obtained by increasing fuel ratio and decreasing spray distances, particles are well molten and strike with high velocities.
c. A comparison of the as-sprayed microstructures of the APS and D-gun coated Al_2O_3 coatings reveals that the APS coating is less dense relative to the D-gun coating.
d. The hardness of D-gun coatings is consistently higher than that of APS coatings.

Result of Wear test results were

a. From both the coating characterization results, it has been observed that the calculated relative abrasion wear resistance (RAWR) tends to follow trends similar to that of the hardness.
b. The variation in the wear rates for all the coatings indicates that all the APS coatings exhibit a slightly higher wear rate than the corresponding D-gun coatings.

RamazanYilmaz [4], studied that how SiC particulate effect on the microstructure, wear resistance and hardness of the coating [5]. To achieve the purpose

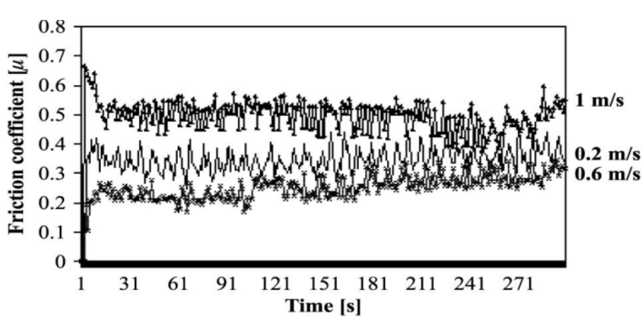
a. Hardness and sliding test, surface roughness measurements were carried out.
b. Microstuctural examination by optical microscope was also conducted.

Table 1: Powder characteristics and spraying conditions for the deposition of the bond layer and ceramic coat [4]

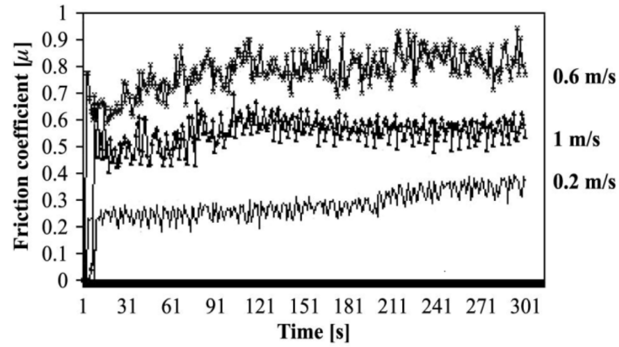
Parameters	Bond coat (Ni +Mo + Al)	Ceramic coat (Al2O3 · TiO2)
Grain size (μm)	-105 +45	-45 + 5
Operation conditions arc current (A)	500	500
Arc voltage (V)	70	70
Primary plasma gas	Ar	Ar
Flow rate of primary gas (ml/m)	100	100
Secondary plasma gas	H2	H2
Flow rate of secondary gas (ml/m)	15	15
Feeding gas	Ar	Ar
Flow rate of feeding gas (ml/m)	40	40
Powder feed rate (g/m)	60	70
Spraying distance (mm)	175	100

Results obtained were

a. This study shows that SiC particles contributed to the lowering porosity and roughness of the coating.
b. The friction coefficient increases with speed and addition of SiC particles shown higher wear resistances.



(a) $Al_2O_3.TiO_2$ coating



(b) SiC reinforced $Al_2O_3.TiO_2$ coating

Fig. 1: Coefficient of friction as a function of sliding duration [4]

J.K.N. Murthy et al [6], studied the effect on erosion behaviour of a WC–Co–Cr coating after grinding. As a part of this work a comparison has also been brought out between two high velocity coating processes namely high velocity oxy-fuel (HVOF) and D-Gun spray process (D-Gun) [7-8].Characterizations that have been carried out for coatings were:

a. X-ray diffraction (XRD)
b. Surface roughness was measured on the coating in as-sprayed condition.
c. X-Ray Diffraction.
d. Scanning electron microscopy (SEM).

Table 2: Coating powder characteristics [6]

	WC–Co–Cr (SM 5847)
Composition	10 wt.% Co 4 wt.% Cr 86 wt.% WC
Particle size	(−53 + 11) μm
Shape	Mostly spherical
Manufacturing	Route Agglomerated/sintered

Results obtain after the experiment were:

Table 3: Coating characteristics of as-sprayed coating [6]

	WC–Co–Cr	
	HVOF	DS
Microhardness (HV0.3)	792	849
Porosity (%)	1.6	1.3
Average surface roughness, Ra (mm)	3.93	4. 05

a. D-Gun coating is expected to give slightly higher micro hardness value and also lower porosity than HVOF
b. Surface roughness was higher in the D- Gun coating than HVOF

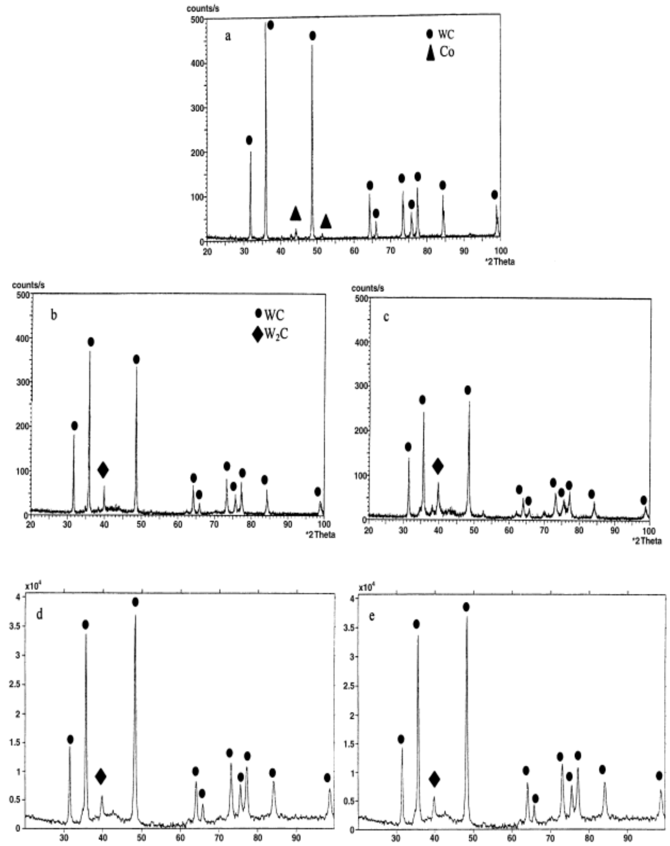


Fig. 2: XRD patterns (a) WC–10Co–4Cr powder; (b) and (c) HVOF and DS coatings, respectively, in as-sprayed condition; (d) and (e) HVOF and D-Gun spray coatings, respectively, in as-ground condition [6]

Chang Jiu et al [9], did an experiment to investigate the structural feature of D-gun sprayed Al_2O_3 coating using a copper electroplating technique [10-11]. Laminar bonding between flattered particles in D-Gun sprayed Al_2O_3 coating is very poor.

Results obtained were

a. It was observed that the coating is relatively dense compared with plasma sprayed coatings based on the process represented by the black area.
b. The distribution of the copper reveals the pores structure in the coating. It also tells that the D-Gun coating mainly consists of well flattered particles.

Ashok Kr. Mishra et al [12], used stir casting process for the study of tribological behaviour of aluminium alloy Al-6061 reinforced with silicon carbide particles [13-15]. Experiment used following:

a. Dry sliding wear test using a pin-on-disc wear tester.
b. Experiments were conducted based on the plan of experiments generated through Taguchi"s technique.
c. ANOVA and regression equation for each response were developed for both 10% & 15% SiC reinforced Al-6061MMCs.

Table 4: Confirmation Experiment for Wear Rate and Coefficient of Friction [12]

MMC	Exp. No.	Load(N)	Sliding Speed(m/s)	Sliding Distance(m)
Al- 6061 + 10%Sic	1	13	2.4	1200
	2	19	2.8	1800
	3	28	3.5	2200
Al- 6061 + 15%Sic	1	13	2.4	1200
	2	19	2.8	1800
	3	28	3.5	2200

Results obtained wer

a. Sliding distance & applied load have the highest influence on wear rate in both composites.
b. Similarly applied load is only parameter which is largely influence the coefficient of friction in both composites.

P. Saravanan et al [16], did an experimental study of the D-gun spraying of Al_2O_3 powder. Taguchi (L16) full factorial design parametric study was used to optimize the D-gun spray process parameters. Optical microscopy, (SEM), X-ray diffraction, image analysis and hardness testing were used for characterization

Table 5: Contribution ratios and optimized levels for the main variables [16]

Desired coating attribute	Processing factors (r%/ level)			
	Fuel to O2 ratio (X1)	Carrier gas flow rate (X2)	Spray distance (X3)	Frequency of detonations (X4)
Low roughness	6.6/+1	12.8/+1	3.07/+1	0
High hardness	6.0/+1	21.3/+1	69.2/−1	0.8/+1
Low porosity	15.7/+1	40.5/+1	27.1/−1	0.1/−1

Results obtained were

a. SEM examination of the coatings showed that none of the coatings indicated any cracking and coatings produced in the experimental matrix may be graded from good to excellent in quality
b. The process parameters did not have any significant influence on the surface roughness.
c. For hardness the significant factors of influence were spray distance, carrier gas flow rate and fuel to O_2 ratio taken in that order.

4. CONCLUSION

From all the above studies we come to know about the mechanical and microstructural characterization of the coatings. These all the studies conclude following points

a. Characterization is an important process for the future of the coatings.
b. Materials can be studied more scientifically by doing characterization.
c. Characterization explains us the effect of coating materials have on the substrate.

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