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Prediction Of Interactions Between Various Input Process Parameters Involved In Detonation Gun Coating Technique Through Response Surface Methodology

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ABSTRACT

Thermal spray coating process is an effective method to enhance the surface of the material. Detonation gun spray coating method (D-Spray) is one of the effective Thermal spray coating process . The material surface or substrate will be enhanced by deposition of coating powders such as metal oxides and ceramics like aluminium oxides, tungsten carbide ,nickel chromium etc by D-spray method that prevents the metal from corrosion and to increase the wear resistance and microhardness. This coating process had wide applications in different engineering sectors such as aviation industry, marine industry, biomedical industry etc., In this Experimental study the optimization of Process parameter of D-spray coating process was done by Taguchi method in order to find the best processing conditions and to get higher quality of coating. Microhardness was estimated for various combinations of parameters and also the microhardness values has been predicted from the observation of interaction between fuel flow rate and coating thickness , powder flow rate and coating thickness, powder flow rate and fuel flow rate through RSM. An equation was derived to find out the micro hardness value for different input parameters of coating thickness(microns), powder flow rate(g/min) ,fuel flow rate (fmr) which gives the intermediate values of process parameters.

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Keywords: Detonation gun, Taguchi method, RSM

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1. INTRODUCTION

Detonation Gun Spray Coating

The Detonation gun coating process [1] consists of a long water cooled barrel with gas and powder inlet valves. Oxygen and fuel (acetylene most common) is fed into the barrel along with a charge of powder .The gas mixture will be ignited by spark and the resulting detonation heats and accelerates the powder to supersonic velocity down the barrel. A pulse of nitrogen is used to purge the barrel after each detonation. This process will be repeated many times a second. The high kinetic energy of the hot powder particles on impact with the substrate result in a build-up of a very dense and strong coating. In this study coating was carried out on substrate and its effects were discussed which is to improve the surface enhancement property. This paper deals with method involves, fuel flow rate, powder feed rate, spray distance with various levels and its effect.

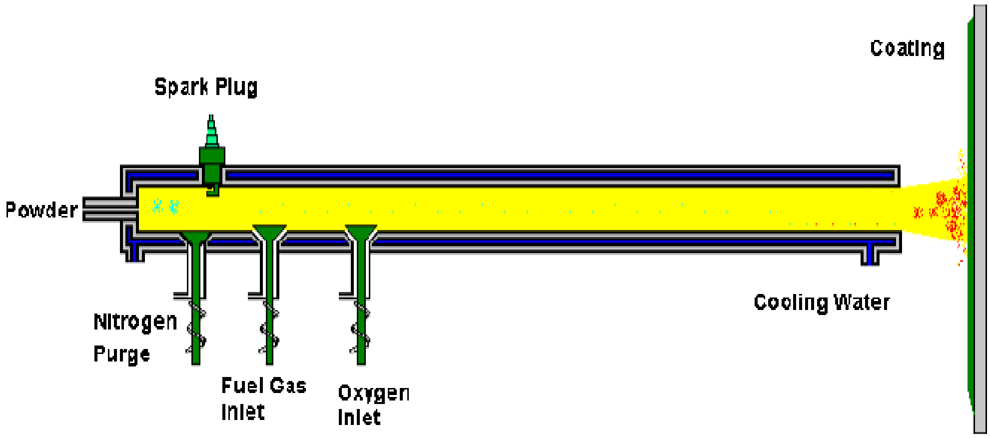

Fig. 1. (a) first picture; (b) second picture.

2. Literature Survey

J.M. Guilemany from Thermal Spray Centre (CPT). Universitat de Barcelona, C/Martí i Franqués spain (2006) conducted WC-Co HVOF coatings to enhance the properties of substrate with the use of use of nanostructured and microstructured feedstock powders which results nano structured powders attains higher microhardness[2]. The optimization and characterization of High Velocity oxy fuel Sprayed coatings was discussed by Maria Oksa from VTT Technical Research centre of Finland T (2011)[3]. The optimization technique had an impact on surface enhancement which was experimentally investigated BY Sheng Hong from Institute of Metals and Protection, College of Mechanics and Materials, Hohai University china (2014) by taguchi technique[4].

3. EXPERIMENTAL PROCEDURE

3.1 Substrate and Coating Powder

The coating process will be carried over the substrate. In our experiment ss304 as substrate Coating powder as WC-NiCr ,which is sprayed over the substrate uniformly to obtain properties such as uniform distribution, better melt flow, particle size and distribution. Microhardness values has been calculated from the experiment.

3.2 Design of experiment by Taguchi Principle

According to taugchi principle, the factor and the levels has to be selected to conduct experiment[5].Such selection can be done with the help of orthogonal array table.in our experiment consists of four factors and three levels.

For four factors and three levels L9 orthogonal array can be selected.

Table 1. An example of a table.

Exp. No.	Factor A	Factor B	Factor C	Factor D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

To analyze the responses TAGUCHI's higher- the- better model is used as given in the following equation (1)

$$\eta = -10\log10\ (1/y2) \quad (1)$$

Table 2. Experimental setup with the factor and level table.

Exp. No.	Coating Thickness (microns)	Fuel Flow Rate	Powder Feed Rate (g/min)	Powder Feed Rate (g/min)
1	300	30	25	6
2	300	34	30	7
3	300	38	35	8
4	350	30	30	8
5	350	34	35	6
6	350	38	25	7
7	400	30	35	7
8	400	34	25	8
9	400	38	30	6

The designed experiments were conducted as given in table 2 and the micro hardness, were found out as given in table 3.

Table 3 Experimental value of Micro hardness

Exp. No.	1	2	3	Y (mean)	D
1	220.9	228.2	226.3	225.13	47.04866
2	219.9	222.9	225.8	222.86	46.96064
3	205	223.4	227.5	218.63	46.79419
4	218.6	214.6	220.1	217.76	46.75956
5	215.7	212.3	217.6	215.2	46.65684
6	219.8	215.9	220.5	218.73	46.79816
7	218.5	222.7	217.4	219.53	46.82987
8	221.0	224.1	219.4	221.5	46.90747
9	220.4	215.4	219.0	218.26	46.77948

Table 4. Factor Effect of Single Coating Powder on Microhardness

Factors	Level 1	Level 2	Level 3
A (thickness)	46.9344	46.7381	46.8389
B (fuel flow rate)	46.8793	46.8416	46.7906
C (powder feed rate)	46.9180	46.8332	46.7603
D (spray distance)	46.8283	46.8628	46.8204

4.0. RSM

The RSM has been analysed and interactions between parameters such as coating thickness, fuel flow rate, powder flow rate and microhardness were predicted.

Table 5. RSM Predictions

Exp.No	Coating Thick	Fuel Flow Rate	Powder Flow Rate	Micro hardness
1	300	30	25	225.13
2	300	30	30	223.16
3	300	30	35	221.29
4	300	34	25	224.38
5	300	34	30	222.86
6	300	34	35	220.34
7	300	38	25	223.06
8	300	38	30	220.89
9	300	38	35	218.63
10	350	30	25	220.32
11	350	30	30	217.76
12	350	30	35	216.35
13	350	34	20	219.36
14	350	34	30	217.23
15	350	34	35	215.2
16	350	38	25	218.73
17	350	38	30	215.96
18	350	38	35	214.15
19	400	30	25	222.89

20	400	30	30	220.72
21	400	30	35	219.53
22	400	34	25	221.5
23	400	34	30	219.76
24	400	34	35	217.93
25	400	38	25	220.62
26	400	38	30	218.26
27	400	38	35	216.66

RSM MODEL

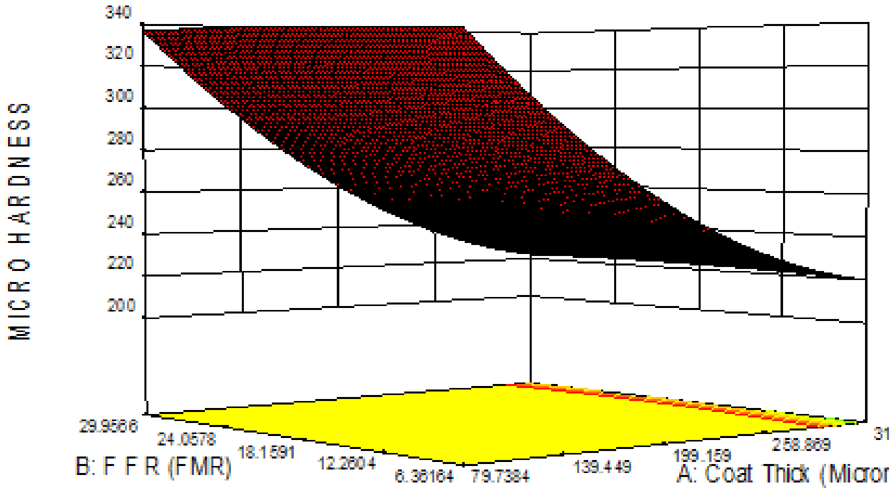

Figure :1. Interaction between Coating Thickness VS FFR

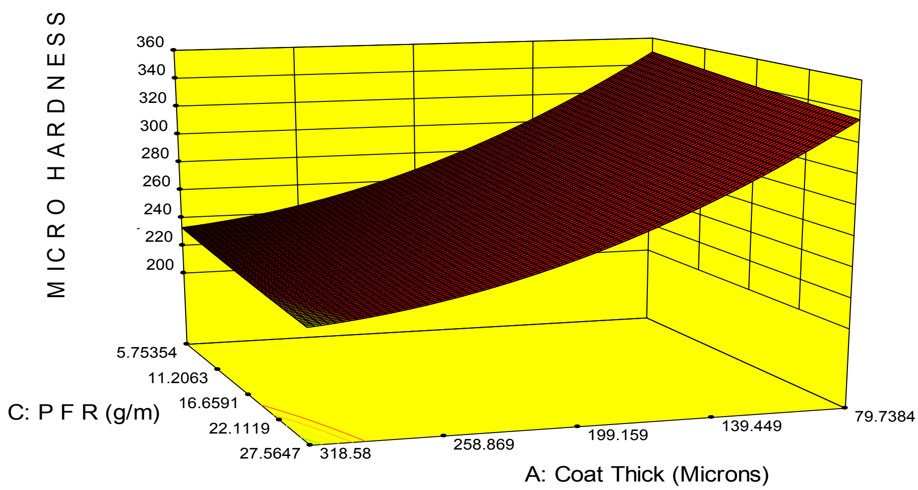

Fig. 2. Interaction between Coating Thickness VS PFR

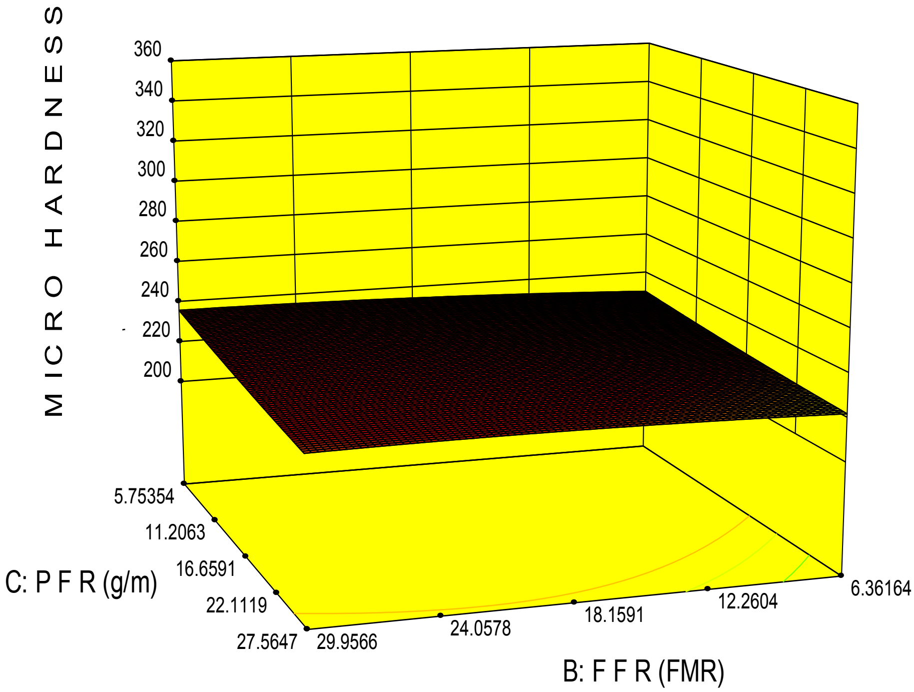

Fig. 3. Interaction between PFR VS FF

Table 6. ANOVA for Response Surface Quadratic model

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	206.00	9	22.89	265.59	<0.0001	significant
A-Coat Thick	71.53	1	71.53	829.97	<0.0001	
B-F F R	0.048	1	0.048	0.56	0.4661	
C-P F R	0.99	1	0.99	11.50	0.0035	
AB	0.030	1	0.030	0.35	0.5629	
AC	0.14	1	0.17	1.95	0.1806	
BC	0.27	1	0.27	3.13	0.0947	
A^2	84.35	1	84.35	978.78	<0.0001	
B^2	0.17	1	0.17	1.95	0.1809	
C^2	0.15	1	0.15	1.77	0.2010	
Residual	1.47	17	0.086			
Cor Total	207.46	26				

The Model F-value of 265.59 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, C, A^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

Table 6. Final Equation in Terms of Coded Factors

MICRO HARDNESS	Level 1
+262.07	
-57.22	*A
+2.22	*B
-5.69	*C
-0.35	*AB
+0.62	*AC
-0.96	*BC
+21.39	*A^2
-1.45	*B^2
+0.76	*C^2

The following equation (4.1) is derived from the RSM analysis and it can be used to predict the microhardness values for different intermediate levels of the input parameters of coating thickness (A), Powder flow Rate(B) and Fuel Flow rate (c).

Micro hardness= 262.07-57.22*A+2.22*B-5.69*C-0.35*AB+0.62*AC-0.96*BC+21.39*A2-1.45*B2+0.76*C2 (2)

5. CONCLUSION

Tungsten carbide nickel chromium was coated on one side of stainless steel 304 by D- spray coating. According to our experiment nine samples were coated with single powder and also with different powder feed rate, Spray distance and thickness. By using taugchi principle, we were able to design the orthogonal array and the micro hardness values has been found. The RSM has been predicted .From the fig 1it was predicted that fuel flow rate was not having much effect on the micro hardness whereas micro hardness increases with the coating thickness.from fig 2.it was found that the micro hardness was not influenced by powder flow rate and also it was observed that as increase in micro hardness with increase of coating thickness.fig 3 it was observed that the powder flow rate and fuel flow rate was not having any impact on micro hardness enhancement. We conclude that coating powder and fuel flow rate was not influenced with micro hardness. The micro hardness increases with increase in coating thickness. An equation has been derived for the micro hardness.

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