WEAR RESISTANCE INVESTIGATION OF HIGH VELOCITY OXY FUEL SPRAY COATING ON AISI 1015 MILD STEEL SUBSTRATE

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ABSTRACT

High velocity oxy fuel spray coating process is an effective surface engineering technique for its good thermal protectiveness, high hardness and wears resistance. The process covers a wide range of industrial applications including manufacturing, textile, and paper industries, and so on. To improve the micro hardness and wear resistance of mechanical components, high velocity oxy fuel coating has been applied to deposit of WC-17Co coating on low carbon AISI1015 substrate. The phase constituents and microstructure of the composite coating will investigate using optical microscope (metallurgical). Hardness at the coating cross section and wear rate measurement. For Experimental design full factorial method was used ($L=m^n$) to find out number of readings. To find out percentage contribution of each input parameters for obtaining optimal conditions, Analysis of variance (ANOVA) method was used. The grey relational grade obtained with use of grey relational analysis technique. By analyzing the Grey relational grade the optimum parameters were evaluated.

Keyword: *coating material, substrate material, HVOF process, wear, micro hardness, full factorial methodology.*

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1 INTRODUCTION

The HVOF process efficiently combusts oxygen and a gaseous or liquid fuel to produce high kinetic energy with controlled heat input. The coating material, in powder form, is introduced into and uniformly heated by the hot gas stream to a molten or semi-molten condition. The flame and powder are accelerated by a converging / diverging nozzle (air cap) to produce supersonic gas and particle velocities, which propel the powder particles toward the substrate to be coated. The powder particles flatten plastically upon impact with the substrate; cooling and solidifying to form the coating. High particle velocities, uniform heating and low dwell time combine to produce coatings that are very dense and tightly bonded to the substrate. Coating chemistries are more predictable and coatings have fine, homogeneous microstructures [1].

Coating of Materials Choose from a wide variety of coating materials including pure metals, metallic alloys, metallic blends, carbides and self-fluxing materials, tailored to gas or liquid fuel systems. Fuels like Gas-fueled systems can use hydrogen, ethylene, propane, propylene or natural gas. Liquid-fueled system scan use Jet-A or kerosene. Choose the fuel process that is suitable to your production requirements, economics and coating quality needed. System Options**.** Choose the system configuration that fits your budget and production requirements, with a choice of standard and customized part manipulators and gun manipulators [1].

HVOF is better than PVD because it has low capital cost , low temperature then pvd .it has high deposition rate .is is ideal for coating large size components .it has Higher density (lower porosity) due to greater particle impact velocities . Improved corrosion protection due to less through porosity. Higher hardness due to less degradation of carbide phases. Thermally sprayed WC–Co coatings, of the order of 200–400 mm thick[2], are widely used in many industries as they offer an effective and economic method of conferring wear resistance without compromising other attributes of the component. High velocity oxy-fuel HVOF. Thermal spraying has shown itself to be one of the better methods for depositing WC–Co powders because the higher velocities and lower temperature experienced by the powder particles as compared to plasma and the results in higher quality, more wear-resistant coatings, with higher levels of retained WC and less porosity. However, the effects of powder morphology, type of HVOF spray system and spray parameters have all been shown to affect the coating microstructure and, in turn, the wear resistance . Therefore, study whether the benefits of increased hardness and wear resistance, observed in sintered nano composite WC–Co cermets, can be readily realized when they are sprayed as coatings by the HVOF method.

Mild (low carbon AISI 1015) steel has a reasonable strength and hardness; it is easier to weld than stainless, and it is cheaper. An important property of mild steels that you lose with stainless steel is ductility, the ability of a material to withstand plastic deformation without breaking. Due to the large application of mild steal and its cheaper cost it is coated with wc based cermets and used instead of S.S [3]. Deposition Materials WC based cermets WC-17Co cermets coating due to the high-impact velocities and the relatively low spraying temperature. The hard WC particle in the coating leads to high coating hardness and high wear resistance, while the metal binder (Co or Co-Cr) supplies the necessary coating toughness here we choose WC-17Co because comparably WC-12Co and WC-Co-Cr the wear rate in WC-17Co is very less.

2. DESIGN OF EXPERIMENT

Design of experiments was developed in the early 1920s by Sir Ronald Fisher at the Rothamsted Agriculture field Research Station in London, England. His initial experiments were concerned with determining the effect of various fertilizers on different plots of land. The final condition of the crop was not only dependent on the fertilizer but also on the number of other factors (such as underlying soil condition, moisture content of the soil, etc.) of each of the respective plots. Fishers used DOE which could differentiate the effect of fertilizer and the effect of other factors. Since that time the DOE has been widely accepted in agricultural as well as Engineering Science. Design of experiments has become an important methodology that maximizes the knowledge gained from experimental data by using a smart positioning of points in the space. This methodology provides a strong tool to design and analyze experiments; it eliminates redundant observations and reduces the time and resources to make experiments. We have used full factorial design, if the numbers of levels and numbers of factors known then the possible design L is

$$L=M^n \quad \dots (1)$$

Where, M = number of levels for each factor, and n = number of factors.

3. HVOF COATING

Fig1: 27 M.S Work Pieces

Fig2: HVOF Coating process

Fig3:Coated piece

The design of input parameter is selected by full factorial method because here we chose 3 factor and 3 level which given 27 result and which is covered all possibility and give best result .The HVOF coating is done 27 mild steel AISI1015 surface. The input parameter and level are given in below table and the other process parameters are shown in table. The size of coating work piece is 50mm X 12mm X12 mm.

Table 1: Variable Input parameters for HVOF coating

Factors	Level 1	Level 2	Level 3
Gas Flow Rate (L/min)	45	55	60
Powder feed rate (g/m)	35	45	50
Stand off distance (mm)	177.8	190.5	203.2

Table2: Constant parameters for HVOF coating

Fuel Options	H2, CH4, C2H4, C3H6, C3H8
Oxygen pressure	10.0 Kg/Cm^2
Air pressure	07.0 Kg/Cm^2
Gas pressure	07.0 Kg/Cm^2
oxygen flow rate	250-350 LPM
Air flow rate	600 – 700 LPM
Gas flow rate	35-80 LPM
Particle size	- 45 + 15 µm

4. TEST RESULTS

After the coating process , micro hardness is measured by Vickers micro hardness test ,wear is measured on pin on disc tribometer and the surface roughness is measured by surface roughness tester.

Table3 : Testing Result

Exp.N0	gas flow	powder feed rate	standoff distance	Micro Hardness (VHN)	Wear In micrometer	Surface roughness micrometer
1	45	35	177.8	967.33	63.000	4.262
2	45	35	190.5	991.00	47.000	4.352
3	45	35	203.2	1011.67	57.300	3.876
4	45	45	177.8	1019.00	50.000	3.932
5	45	45	190.5	1032.00	34.000	3.532
6	45	45	203.2	1047.00	43.000	3.428
7	45	50	177.8	1012.67	69.000	4.152
8	45	50	190.5	1036.00	37.000	4.163
9	45	50	203.2	1042.33	51.000	3.764
10	55	35	177.8	1013.00	52.000	4.282
11	55	35	190.5	1027.00	38.500	4.119
12	55	35	203.2	1041.33	44.500	3.892
13	55	45	177.8	1064.00	34.000	3.816
14	55	45	190.5	1097.00	15.600	3.808
15	55	45	203.2	1079.33	22.400	3.454
16	55	50	177.8	1071.00	54.634	4.384
17	55	50	190.5	1101.00	33.450	4.122
18	55	50	203.2	1110.00	40.000	3.768
19	60	35	177.8	1034.00	53.400	3.942
20	60	35	190.5	1097.33	35.630	3.752
21	60	35	203.2	1066.67	46.800	3.264
22	60	45	177.8	1105.00	27.000	3.012
23	60	45	190.5	1138.00	12.670	3.124
24	60	45	203.2	1156.00	16.256	3.089
25	60	50	177.8	1108.00	43.600	3.428
26	60	50	190.5	1120.00	25.000	3.8
27	60	50	203.2	1151.00	29.000	3.126

5. ANOVA ANALYSIS

Table 4: ANOVA %contribution

Parameters	**Hardness** *%contribution*	**Wear** *%contribution*	**Roughness** *%contribution*
Gas Flow Rate (L/min)	57.86 %,	28.47 %,	42.70 %
Powder feed rate (g/m)	28.30 %	36.05 %	28.89 %
Stand off distance (mm)	9.31 %	28.96 %	19.05 %
Error	4.53 %	6.52 %.	09.36 %

6. MAIN EFFECTS PLOT

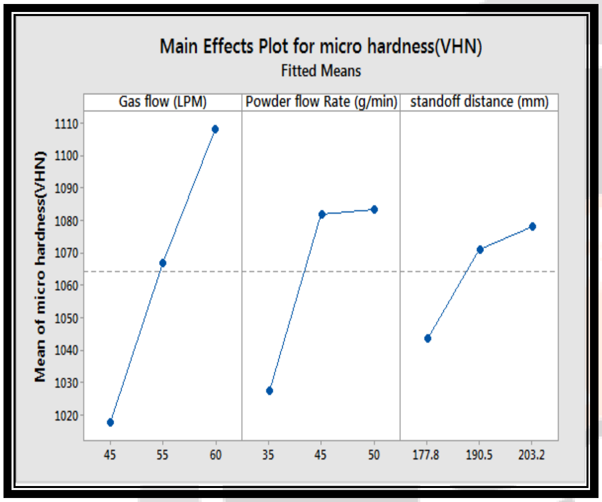

fig4: main effect for hardness

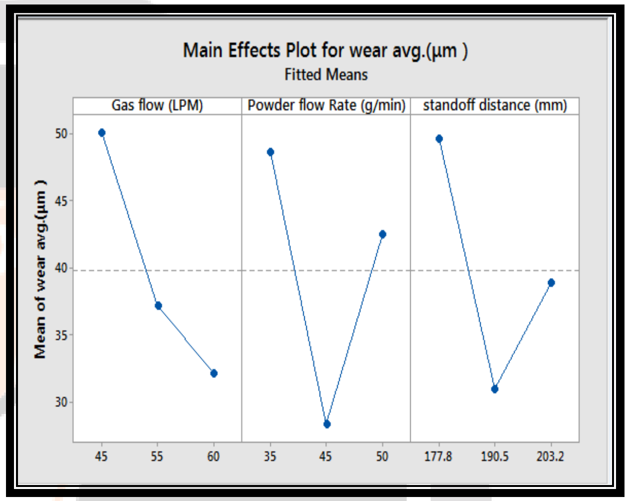

Fig5: main effect for Wear

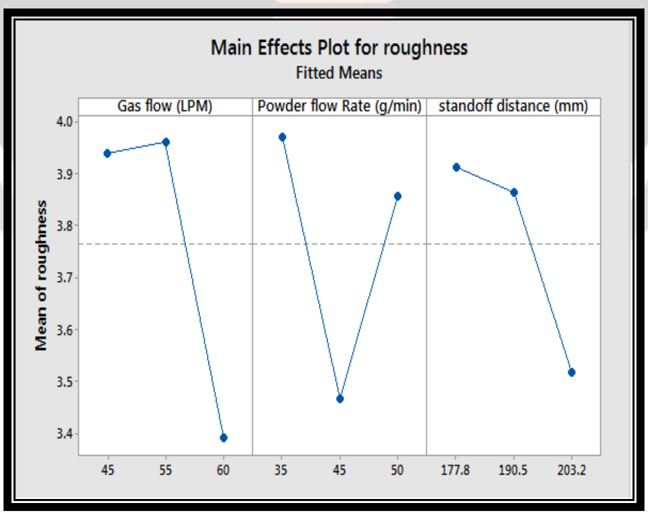

Fig6: main effect for roughness

7. GREY RELATIONAL ANALYSIS

In grey relational generation, the normalized data corresponding to Lower-the-Better (LB) Criterion can be expressed as:

$$Xi(k) = \frac{\max yi(k) - yi(k)}{\max yi(k) - \min yi(k)}$$

For Higher-The-Better (Hb) Criterion, The Normalized Data Can Be Expressed As:

$$Xi(k) = \frac{yi(k) - minyi(k)}{maxyi(k) - minyi(k)}$$

Where xi (k) is the value after the grey relational generation, min $y_i(k)$ is the smallest value of $y_i(k)$ for the k_{th} response, and max y_i (k) is the largest value of $y_i(k)$ for the k_{th} response. An ideal sequence is x_0 (k) for the responses. However, if there is ‘‘a specific target value’’, then the original sequence is normalized using,

$$Xi(k) = 1 - \frac{|yi(k) - OB|}{\max\{\max yi(k) - OB, OB - \min yi\ (k)\}}$$

The purpose of Grey relational grade is to reveal the degrees of relation between the sequences say, [x0 (k) and xi (k), i =1, 2, 3…, n]. The Grey relational coefficient can be calculated using the preprocessed sequences. The Grey relational coefficient is defined as follows

$$\xi i(k) = \frac{min\,\Delta + \theta max\,\Delta}{\Delta i\ (k) + \theta max\,\Delta};$$

The Grey relational grade γi can be computed as : $yi = \frac{1}{n}\sum_{k=1}^{n} \xi i\ (k)$

Table 5: GRC and GRG and GRG NO.

Exp .N0	Micro Hardness (VHN) GRC	Wear In micrometer GRC	Roughness GRC	GRG	GRG NO
1	0.333333333	0.358812663	0.354338843	0.34882828	27
2	0.363757302	0.450676054	0.338598223	0.38434386	25
3	0.39526114	0.386908442	0.442580645	0.408250076	23
4	0.407785247	0.430032827	0.427148194	0.421655423	21
5	0.432065404	0.569047379	0.568822554	0.523311779	13
6	0.46393882	0.481494145	0.622504537	0.522645834	14
7	0.396924242	0.333333333	0.375684556	0.368647377	26
8	0.44012877	0.536527288	0.373434948	0.450030335	18
9	0.453522752	0.423565682	0.47705146	0.451379965	17
10	0.397476141	0.41729017	0.350715746	0.388494019	24
11	0.42239237	0.521622372	0.382598996	0.442204579	19
12	0.451352838	0.469455788	0.438058748	0.452955791	16
13	0.506265597	0.569047379	0.460402685	0.51190522	15
14	0.615221574	0.905772632	0.462887989	0.661294065	5
15	0.551650537	0.743237894	0.608156028	0.634348153	6
16	0.52602671	0.40161702	0.333333333	0.420325688	22
17	0.631700539	0.575441822	0.381959911	0.529700757	12
18	0.672212919	0.5075232	0.475728155	0.551821425	10
19	0.436059815	0.408810509	0.42450495	0.423125091	20
20	0.616548479	0.550904645	0.481065919	0.549506348	11
21	0.513625351	0.452122963	0.731343284	0.565697199	9
22	0.649086593	0.662783857	1	0.770623483	4
23	0.839764989	1	0.859649123	0.899804704	2
24	1	0.887058675	0.899082569	0.928713748	1
25	0.662767415	0.476605466	0.622504537	0.587292473	8
26	0.723788698	0.695517965	0.465400271	0.628235645	7
27	0.949665274	0.632992471	0.8575	0.813385915	3

Table 6 Analysis of Variance for Grey Relational Grade:

Source	**DF**	Adj SS	Adj MS	F	**P**	
Gas flow	2	0.30433	0.152163	43.53	0.000	S = 0.0591247 R-sq = 89.24% R-sq(adj) = 86.01% R-sq(pred) =80.39%
Powder feed rate	2	0.20389	0.101947	29.16	0.000	
SOD	2	0.07175	0.035874	10.26	0.001	
Error	20	0.06991	0.003496			
Total	26	0.64988				

8. CONCLUSION

Analysis of Micro hardness shows the percentage contribution of individual parameters in HVOF coating Process for Gas flow is 57.86 %, Powder feed rate of 28.30 %and Stand Off Distance of 9.31 %and the error is 4.53% . This error is due to human ineffectiveness and machine vibration . Analysis of wear shows the percentage contribution of individual parameters on HVOF coating Process for Gas flow is 28.47 %, Gas flow of 36.05% and Stand Off Distance of 28.96%and the error is of 6.52%.This error is due to human ineffectiveness and machine vibration. Analysis of roughness shows the percentage contribution of individual parameters on HVOF coating Process for Gas flow is 42.70%, Powder feed rate of 28.89% and Stand Off Distance of 19.05% and the error is of 09.36%. This error is due to human ineffectiveness and machine vibration By use of GRA optimization technique the optimal parameter combination is meeting at experiment 24 for HVOF coating and it is occur at 60 (LPM) Gas flow, 203.2(mm) Stand Off Distance and 45(g/m) powder flow rate.

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