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STUDY OF THE EFFECT OF COATING POWDERS (WC:12CO, WC:10 CO-4-CR , CRC2-25-NICR) ON THE SURFACE ROUGHNESS

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ABSTRACT

When machines with higher performance efficiency are in great demands today, producers aim to provide a perfect finish for their products. This might aim to optimize several properties of the machine or component for specific purposes. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth ones. Certain components need to be perfectly smoothened where as some requires a particular level of uniform roughness .Usually roughness value is evaluated mainly for coated specimen. In this experiment also, we have optimized certain parameters using Taguchi to attain a surface with adequate roughness.

Keywords*: Detonation gun spray coating, Process Parameter Optimization, Taguchi method, greater hardness and ANOVA*

1. Introduction

Surface roughness, often shortened to roughness, is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface.

Although roughness is often undesirable, it is difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase exponentially its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

2. Experiment

2.1 Substrate

A suitable low cost substrate was to be chosen over which coating could be done. For this SS316 was chosen. SS316 is a marine grade stainless steel used for making chemical containers. Square pieces of SS316 of dimensions 4 x 4 inches were used over which coating was to be done.

2.2 Coating Process

The square pieces of SS316 were thermally sprayed using Detonation gun. A schematic diagram of the gun is depicted below:

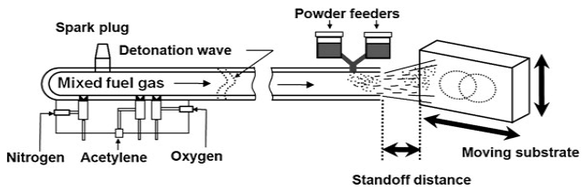

Fig. 1 Detonation Gun Process

As shown in the figure the gun consists of inlet for fuel and oxygen. Acetylene in generally used as a fuel. A powder feeder is used to feed the powder to be coated into the barrel. A spark is used to ignite the entire mixture of fuel ,oxygen and powder and the resulting detonation accelerates the entire gas mixture at high velocity down the barrel .During the process the powder melts due to the high temperature and gets coated over the surface to be coated.[1]

A nitrogen pulse is used to purge the barrel after each detonation. During the process of coating the surface to be coated is moved in three axes as shown in figure to form a thick uniform coat.

2.3 Roughness test

The roughness test was carried out with the help of Profileograph instrument. Profileograph is an instrument for measuring smoothness of a surface (as of a metal casting) by amplification of the minute variations from the plane or arc of smoothness .The

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instrument measures the Ra and Rz values to evaluate the roughness of a surface. The surface is coated controlling certain parameters as depicted in the table below.

Table: 1 Experiment Conducted as per L9 Orthogonal Array

S.No	POWDER (A)	COATING THICKNESS µm (B)	POWDER FLOW RATE Sp l/min (C)	SPRAY DISTANCE cm (D)
1	WC:12Co	350	600	160
2	WC:12Co	450	1000	170
3	WC:12Co	550	1400	180
4	Wc:10 Co-4-Cr	350	1000	180
5	Wc:10 Co-4-Cr	450	1400	160
6	Wc:10 Co-4-Cr	550	600	170
7	CrC2-25-NiCr	350	1400	170
8	CrC2-25-NiCr	450	600	180
9	CrC2-25-NiCr	550	1000	160

The above table depicts the data of the experiments that were conducted as per Taguchi's L9 orthogonal array system. The experiments were conducted as above mentioned order and the responses (Rz values) values are obtained as given in the table 2. In our study the surface finish (smoothness) should be improved. Thus higher the best model was selected for our experiment .The equation (equation no: 1) for higher the best is given below:

$$\eta = -10 \log_{10} (1/Y^2) \quad (1)$$

η – Objective Function

Y – Responses

Fig. 2 Profileograph

2.3.1 Arithmetical mean roughness(Ra):

A section of standard length is sampled from the mean line on the roughness chart. The mean line is laid on a Cartesian coordinate system wherein the mean line runs in the direction of the x-axis and magnification is the y-axis .The value obtained with the formula on the right is expressed in micrometer. Ra is the vertical length between the highest peak of the rough surface and the mean line between the highest and lowest peak.

2.3.2 Ten-point mean roughness (Rz):

A section of standard length is sampled from the mean line on the roughness chart. The distance between the peaks and valleys of the sampled line is measured in the y direction. Rz is the vertical length between the highest peak and lowest peak of a rough surface.

Table: 2 Responses and Calculated Values of Objective Function

1	2	3	a	b	c	Y	ŋ
4.95	5.91	6.17	5.05	6.51	5.68	5.71	15.133
5.26	5.13	6.12	5.21	5.37	4.92	5.33	14.535
5.42	5.26	6.25	5.83	5.55	4.9	5.535	14.862
5.49	4.93	4.59	6.06	5.63	4.72	5.236	14.38
4.82	4.93	5.81	5.34	5.39	4.63	5.155	14.245
6.3	5.76	4.57	5.75	5.39	4.88	5.441	14.714
11.01	8.89	11.15	7.99	8.11	7.67	9.137	19.216
10.6	7.13	10.4	10.21	8.03	7.47	8.973	19.059
8.48	11.98	12.36	12.36	12.28	9.51	11.162	20.955

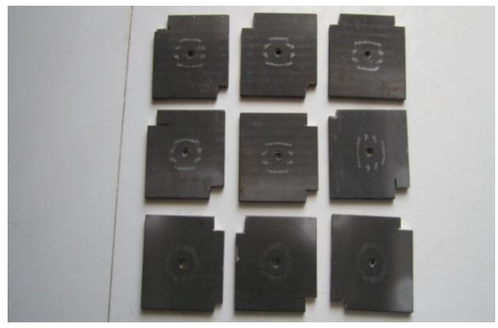

Fig. 3 Coated Samples

Note: Reading 1,2 and 3 are taken in horizontal direction where as a,b and c are taken in vertical direction over the surface.

The effect of various control factors is found out by the following method:

mA1= (1/3) (ŋ1+ŋ2+ŋ3) = 14.843
mA2= (1/3) (ŋ4+ŋ5+ŋ6) = 14.446
mA3= (1/3) (ŋ7+ŋ8+ŋ9) = 19.743

mB1= (1/3) (ŋ1+ŋ4+ŋ7) = 16.243
mB2= (1/3) (ŋ2+ŋ5+ŋ8) = 15.946
mB3= (1/3) (ŋ3+ŋ6+ŋ9) = 16.844
mC1= (1/3) (ŋ1+ŋ6+ŋ8) = 16.302
mC2= (1/3) (ŋ2+ŋ4+ŋ9) = 16.623
mC3= (1/3) (ŋ3+ŋ5+ŋ7) = 16.108

mD1= (1/3) (ŋ1+ŋ5+ŋ9) = 16.777
mD2= (1/3) (ŋ2+ŋ6+ŋ7) = 16.155
mD3= (1/3) (ŋ3+ŋ4+ŋ8) = 16.100

The effects of different factors in different levels are calculated and plotted in the table no. 3.

Where;

mA1 – effect of factor A in level 1
mA2 – effect of factor A in level 2
mA3 – effect of factor A in level 3
mB1 – effect of factor B in level 1
mB2 – effect of factor B in level 2
mB3 – effect of factor B in level 3
mC1 – effect of factor C in level 1
mC2 – effect of factor C in level 2
mC3 – effect of factor C in level 3
mD1 – effect of factor D in level 1
mD2 – effect of factor D in level 2
mD3 – effect of factor D in level 3

Table 3: The values of Individual Effects of Each Control Factors

	1	2	3
mA	14.843	14.446	19.743
mB	16.243	15.946	16.844
mC	16.302	16.623	16.108
mD	16.777	16.155	16.1

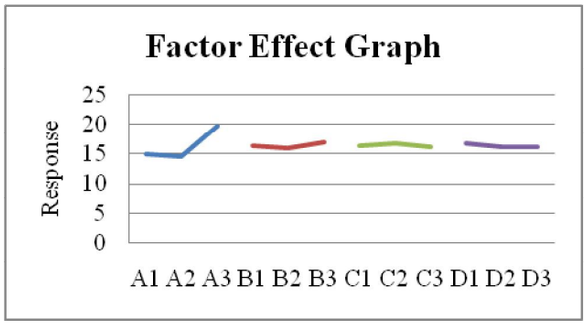

Fig. 4 Factor Effect Diagram

3. Interpretation of the Graph

i. From this graph we can understand that factor A (powder) has the highest influence on the response and factor B (coating thickness) has probably the next higher influence on the response

ii. Combination of A2 , B2 ,C3 and D3 provides the best surface finish For four factors and three levels the total number of possible combinations will be 81. Out of these 81 combinations we tried only 9 combinations. This graph gives the result based on the 9 number of tried combination based on Taguchi method. It means there are rest 72 untried combinations .To get the values of these 72 combinations Taguchi suggested the following formula:

$$ŋ = μ + (mA - μ) + (mB - μ) + (mC - μ) + (mD - μ) \quad (2)$$

Where, μ - average of all ŋ

mA, mB , mC , mD – effect of factors in different levels. For example, if any one wants to find out the result of the untried combinations of A1,B3, C2, D1, the following equation number 3 can be generated:

$$ŋ_{xx} = μ + (mA1 - μ) + (mB3 - μ) + (mC2 - μ) + (mD1 - μ) \quad (3)$$

From the mentioned equation after finding the value of ŋxx, one can easily find out the Y value of the untried combination.

Thus, by Taguchi method the values of not only 9 tried combinations were found out but also the values of the untried 72 combinations were deduced.

4. ANOVA

Taguchi gives the best combination of parameters that can be used to optimize the result that is being studied. It does not serve well to describe the percentage of influence of each parameters on the results obtained. ANOVA technique solves this problem .Through this effective technique of ANOVA the engineers are able to optimize various process without much stress .

ANOVA has been used in this experiment for the same purpose and is described in the following section.

Table 4: ANOVA Tabulation

A	B	C	D	AVG (1)	AVG(2)	TOTAL
1	1	1	1	5.68	5.75	11.43
1	2	2	2	5.5	5.17	10.67
1	3	3	3	5.64	5.43	11.07
2	1	2	3	5.01	5.47	10.48
2	2	3	1	5.19	5.11	10.3
2	3	1	2	5.54	5.34	10.88
3	1	3	2	10.35	7.93	18.28
3	2	1	3	9.38	8.57	17.95
3	3	2	1	10.94	11.38	22.32
					total	1233.8

Correction factor (C.F) = $(1233.8)^2$ /18= 84570.1355

Sum of Square of each parameters:

$S.S_{total}$= (18359.83+16727.64+58062.47)-C.F=8579.8045

$S.S_A$ = $(((331.7)^2/6)+((316.6)^2/6)+((585.5)^2/6))$-C.F =(18337.4+16705.9+57037.5)-C.F=7608.3165

$S.S_{B=}$401.9,389.2,442.7=(26920.6+25246.10+32560) -C.F=260.4545

$S.S_C$=402.6,434.7,396.5=(27014.46+31494.02+2620 2.04)-C.F=140.38

$S.S_D$=440.5,398.3,395=(32340.04+26440.48+26004. 16)-C.F=214.55

$S.S_{Error}$=8675.327(7509.76+157.23+140.38+214.56) =356.1035

The percentage influence of each factor was calculated using this technique of ANOVA. The initial ANOVA and the final ANOVA table are as follows depicted in table number 5 and table number 6 respectively.

Table 5:Initial ANOVA tabulation

SOURCE	SS	DOF	M.S	Fcal
A	7608.317	2	3804.158	96.161
B	260.4545	2	130.227	3.292
C	140.38	2	70.19	1.774
D	214.55	2	107.275	2.712
Error	356.1035	9	39.56	
Total	8579.805	17		

From the above table it is clear that factor C (Powder Flow Rate) holds the least influence on the result of optimum roughness.

Table: 6 Final ANOVA Tabulation

SOURCE	SS	DOF	MS	Fcal	SS1	PERCENTAGE
A	7608.317	2	3804.16	84.284	7518.047	93.52%
B	260.4545	2	130.227	2.885	170.1845	2.12%
D	214.55	2	107.28	2.376	124.28	1.55%
Error	496.483	11	45.135			
Total	8579.805	17			8038.184	2.81%

Hence from the table above it is clear that, factor A (powder composition) has the maximum influence of 93.52% on the surface finish.

5. Conclusion

i. Taguchi's L9 orthogonal array proved to be an efficient technique in optimizing process parameters to achieve desired roughness

ii. Powder Wc:10 Co-4-Cr , coating thickness of 450 µ , powder flow rate of 1400 spray lit/hour and spray distance of 180 mm gives smoothest surface as inferred from the factor effect diagram (figure 4).

iii. ANOVA helped to determine the percentage influence of each parameters on the result that made it easy to achieve desired results.

iv. For further improving the surface finish of the coating , the coating powder can be agglomerated with CNT .This has proved to be an effective method for improving the surface finish .

Nomenclature

μm	- micrometer coating thickness
sp l/min	– spray litres per minutes
SS_A	– Sum of Square of Factor A
SS_B	– Sum of Square of Factor B
SS_C	– Sum of Square of Factor C
SS_D	– Sum of Square of Factor D
SS_{Total}	– Summation of Sum of Square
SS_{Error}	– Sum of square of Error
SS	– Sum of Square
DOF	– Degree of Freedom
M.S	– Mean Square

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