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Process parameter optimization of Detonation gun coating for various coating materials

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Abstract

Various researches have been carried out throughout the world to enhance the hardness and wear resistance of the material. Many coating techniques have been adopted for this. The detonation gun spraying is the most effective coating method for applications like hardness and wears resistance and is widely used .the study deals with optimizing the detonation gun spraying. the experiment was conducted using taughi principle.L4 orthogonal array was adopted for finding the best suited combination to maximize the hardness and minimize the frictional force the microscopic inspection was also conducted to find out the adhesive property of the coating

1.0 INTRODUCTION

Various coating process are used to improve the surface property of various metals for different applications. Thermal spray coating is one of the important processes to improve the wear resistance of the surface. It can also be used to make corrosion free coating. The High velocity Oxy Fuel (HVOF) coating is one among the thermal spray coating. Very thick and hard Surfaces can be obtained through this kind of HVOF coating. HVOF guns are used in various field such as marine, Bio medical, Aerospace etc……Since the process will have very little heating effect on the surface, therefore will not be a chances of changes in the microstructure. Hence these processes are used in various fields.

Thermal spray processes are carried out in different methods like Plasma spray, Arc spray, Detonation Gun Spray, Flame spray etc…… In this study Detonation gun spray method is used to perform the coating process to enhance the micro hardness of the coated surface, the adhesive property and also for the sliding applications.

The following coating results are obtained by the deposition of various particles. Usually the surface of the metal will not be heated up while coating in order to allow the coating of flammable substances. The quality of the coating is assessed by the measurement of bond strength, oxide content, macro and micro hardness, porosity, surface roughness

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1.1 DETONATION GUN COATING

In this method of coating, the material to be coated is mixed with gases such as acetylene and oxygen in the presence of high heat. The coating is being done by using a detonation gun. This instrument is designed in such a way that it detonates the coating material at regular intervals, so that the coating will be unique and uniform in this process of coating either the substrate to be coated or the gun will be moving. When the coating material strikes the metal surface, there occurs the formation of a strong mechanical bond having 10,000 psi strength and the hardness up to 1350 VHN .One of the main advantages of this method is that maintaining low temperature on the surface of the metal due to periodic detonation the microstructure as well as metallurgical property will not change. The detonation gun mixes a certain and measured amount of coating material, acetylene and oxygen. The resultant gas formed will melt or heat the coating material into a plastic state which will be thrown on the substrate material at a very high velocity. Hence the substrate and the coating material is joined with the strong tenacious mechanical bond. The strength of the bond increases above 10000 psi. The hardness of the coating obtained up to 1350 VHN of 10,000 psi. The coating hardness can go beyond 1350 VHN. The desired coating thickness can be obtained by this process.

1.2 STAINLESS STEEL OVERVIEW

The rate of corrosion can be reduced by the addition of alloys to the pure metals. As far as steel is concerned it is having the capability of resisting the diffusion of oxygen to the inner layer .This process is called passivation. Less quantities of chromium is added in order to reduce the rate of corrosion. Usually the metal alone will not have all the desired properties. But the same metal when alloyed will another metal will enhance the property of the resultant. Hence the alloyed metal is most preferred in modern days. For example iron is most corrosive. But when it is alloyed with10.5% chromium , it becomes corrosion resistant .this proves that the alloyed metal has better properties than the normal metal. Hence several properties can be obtained by alloying different metals.

1.2.1 TYPES OF STAINLESS STEEL (Used in our Experiment)

STAINLESS STEEL TYPE 304 (UNS S30400)

In our experiment we preferred stainless steel 304 due to its non magnetic nature. This grade comprises of 8% nickel and 18% chromium. This grade is very less prone to corrosion also. The most popularly used stainless steel is 304 which comprises of 18% chromium and 8% nickel. This steel cannot be hardened and is non magnetic.

STAINLESS STEEL TYPE 202

The hot roll coiled form of steel known as stainless steel 202 has been processed so that it became cold .In accordance with the different parameters, different products are made from this steel when it is in hot rolled form. This steel is first converted into cold rolled coil and it is used according to thee required shape, thickness and width

2. EXPERIMENTS

2.1. APPLYING TAGUCHI IN OUR EXPERIMENT

We have used taughi principle for optimization process

The steps involved in taughi principle are

Step 1: problem definition

Our aim is to enhance the property of the specimen such as adhesiveness and hardness for industrial application and to optimize the property of detonation gun coating.

Step 2: identification of noise factor

These are the factors which are not under our control but can affect the measured output. The stainless steel have certain properties which keeps changing with respect to environment thet cannot be controlled.

Step 3: planning to control the noise factor

We have reduced the noise factor by taking two samples of stainless steel.

Step 4: identification of objective function

Taughi has suggested different formula for various needs like normalizing, reducing and maximizing etc. our need is to obtain the maximum hardness. formula for objective function:

$$n = -10 \log_{10} (1/y2)$$

here
y is the measure value that needs to be optimized
so in our experiment, y=hardness
step 5: identification of control factor and levels
A control factor is defined as one which will have a certain effect on our output. In our experiment, it is hardness. And it will be controlled by us.
Here we have taken 3 control factors and 2 levels.
The following is the tabulation of control factors and levels

Table: 1

Control factors	Level 1	Level 2
Gas Ratio	2.5	1.3
Base Metal	SS 202	SS 304
Coating Powder	75% Chromium Carbide with 25% Nickel Chromium	Al_2O_3

Step 6: design of experiment
Taughi has suggested various arrays according to the number of levels and control factors. Hence we have to choose the required array for our experiment as given by taughi. The table or array is the tabulation of experiments known as the orthogonal array.
The following are the arrays suggested by taughi, the suitable array is chosen for our experiment

Table: 2

No of control Factors	Array to be selected
2 - 3	L4
4 – 7	L8
8 – 11	L12
12 – 15	L16

From the table , the best suitable for our experiment is orthogonal array L4.
Based on the above table the L4 array is chosen and the experimental set up for this array as suggested by taughi is as tabulated below

Table :3

Experiment No.	A	B	C
1	1	1	1
2	1	2	2
3	2	1	2
4	2	2	1

According to the above mentioned experimental setup, our experimented is tabulated as below

Table: 4

Experiment No.	Gas Ratio	Base Metal	Coating Powder
1	2.5	SS202	75% Chromium Carbide with 25% Nickel Chromium
2	2.5	SS304	Al_2O_3
3	1.3	SS202	Al_2O_3
4	1.3	SS304	75% Chromium Carbide with 25% Nickel Chromium

From the table, it is understood that the first experiment should be conducted with gas ratio 2.5, base material SS202 and powder material is 75% chromium carbide with 25%nickel chromium. Then other four experiments are conducted accordingly.

Step 7: conduct the experiment and calculation of Y values

As in step 6, the experiment is conducted and the Y values is calculated accordingly. Here the Y is the micro hardness and it is taken in different points and the average is taken.

Fig. 1 (a) Base Metal, (b) Coated Specimen

Step 8: calculation of objective function:

The formula for calculation of objective function is as below

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

here, we have to substitute the average value in place of Y.

Table :5

Experiment No.	Hardness(Y)				η
1	826	850	840	840	58.47
2	768	777	780	777	57.78
3	1200	1214	1215	1215	61.66
4	1100	1118	1117	1120	60.93

The above is tabulated values of Y and η (objective function).

Step 9: determination of factor effect

This step helps in finding the individual effect of each control factor at each level and is denoted as mA1,mB1etc.

mA_1 means the effect of factor A at level 1

mC_2 means the effect of factor c at level 2

$mA_1 = \frac{1}{2}(\eta_1 + \eta_2) = \frac{1}{2}(58.475 + 57.786) = 58.1305$

$mA_2 = \frac{1}{2}(\eta_3 + \eta_4) = \frac{1}{2}(61.662 + 60.937) = 61.2995$

$mB_1 = \frac{1}{2}(\eta_1 + \eta_3) = \frac{1}{2}(58.475 + 61.662) = 60.0685$

$mB_2 = \frac{1}{2}(\eta_2 + \eta_4) = \frac{1}{2}(57.786 + 60.937) = 59.3615$

$mC_1 = \frac{1}{2}(\eta_1 + \eta_4) = \frac{1}{2}(58.475 + 60.937) = 59.706$

$mC_2 = \frac{1}{2}(\eta_2 + \frac{1}{2}(57.786 + 61.662) = 59.724$

the above values are tabulated and plotted ina graph as shown below.

Table: 6

Factor	Level 1	Level 2
Gas Ratio	58.1305	61.2996
Base Metal	60.0685	59.3615
Powder	59.706	59.724

Factor effects

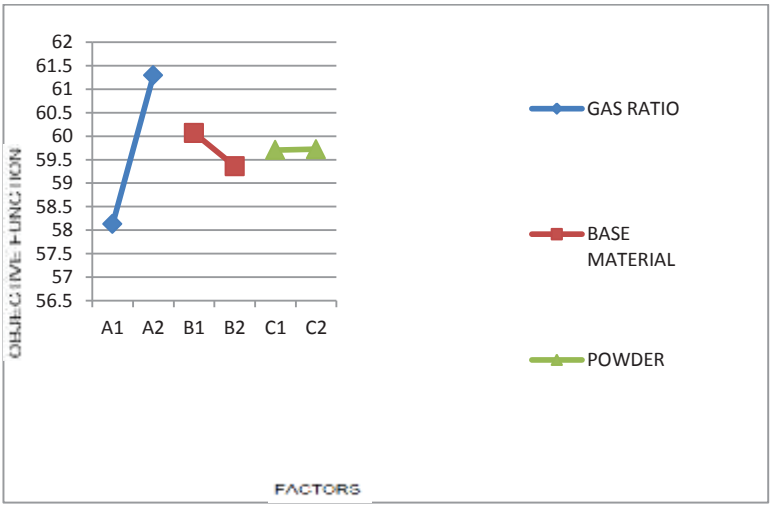


Fig. 2 (Factor effect graph.)

2.1.1.RESULT AND DISCUSSION

The taugchi principle is one of the most useful tools that we have used in this experiment. With this principle we can find out the best combination by conducting very few experiments,, From the graph obtained, we can infer that: Factor A(gas ratio) has the largest effect on hardness. The other factors B(base material) and C (powder)has the least effect on hardness. The maximum hardness is obtained by A2,B1,C2.The minimu hardness is obtained by A1,B2,C1.

Reverse calculation is also possible by taughi principle.

The values of untried combinations can also be obtained from the below formula

$\eta = \mu\,\eta + (mA - \mu\eta) + (mB - \mu\eta) + (\mathrm{mC} - \mu)$

Using the above formula the values can be found out for any combination.

2.2.MICROSCOPIC INSPECTION:

The above four specimens that are experimented are taken and microscopic inspection is done. Various properties have been studied. The main property tested was the adhesiveness. It has been found that the specimen 1 and specimen 4 (75% chromium carbide with 25% nickel chromium)had poor bonding of coating material with the substrate and has many pores on it Hence it has poor adhesive property. The specimen 2 and specimen 3(Al_2O_3) had good bonding of coating material with the substrate. Hence it has good adhesive property.

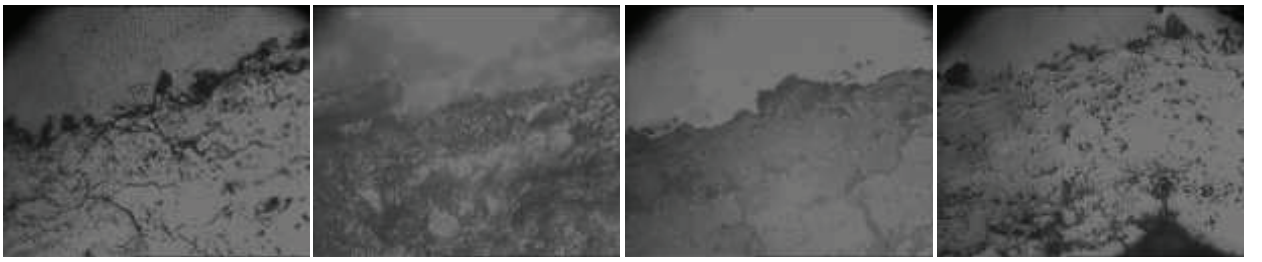


Fig. 3 (a)& (d)75% Chromium Carbide with 25% Nickel Chromium Coating
(b)& (c) Al_2O_3 Coating

2.2.1. RESULT AND DISCUSSION

1.Specimen 1 and specimen 4 has poor adhesive property.
2. specimen 2 and specimen 3 has good adhesive property.

2.3.ANALYSIS OF FRICTIONAL FORCES FOR SLIDING APPLICATION:

The pin on disc test was conducted to find out the frictional forces to find out the sliding applications. The following table shows the result.

Table 7

Experiment No.	Frictional Force	Co-Efficient of friction
1	0.12	0.024
2	2.29	0.457
3	1.82	0.364
4	0.08	0.001

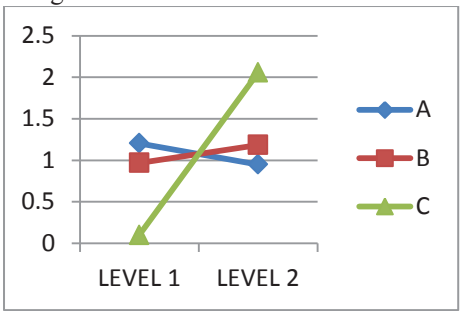
The average response table was constructed to find out the influence of different parameters on sliding applications.
Table: 8

A	B	C	Frictional Force
1	1	1	0.12
1	2	2	2.29
2	1	2	1.82
2	2	1	0.08

Table :9

Factor	L1)	L2	Max- Min	Rank
A	1.205	0.95	0.255	2
B	0.97	1.185	0.215	3
C	0.1	2.055	1.955	1

Using the above tabulated values the following response graph is drawn.



2.3.1.RESULT AND DISCUSSION

For sliding application, the frictional force should be minimum. Therefore the concept of smaller the best can be adopted for sliding applications. The following results were obtained

The factor C (powder) is having more influence on the frictional force.

The combination A2,B1,C1 will be best suited for sliding application as it has minimum friction.

3. 0 CONCLUSION

Micro Hardness

The taugchi principle is one of the most useful tools that we have used in this experiment. With this principle we can find out the best combination by conducting very few experiments,, this is quite a useful method for a researcher. The taugchi principle also helps in Cost reduction and quality improvement. From the graph obtained, we can infer that: Factor A has the largest effect on hardness. The other factors B and C has the least effect on hardness.

The maximum hardness is obtained by A2,B1,C2.The minimum hardness is obtained by A1,B2,C1.

Reverse calculation is also possible by taughi principle.

The values of untried combinations can also be obtained from the below formula

$\eta = \mu\,\eta + (mA - \mu\eta) + (mB - \mu\eta) + (\mathrm{mC} - \mu)$

Using the above formula the values can be found out for any combination.

Microscopic Analysis

1.Specimen 1 and specimen 4 has poor adhesive property.

2. specimen 2 and specimen 3 has good adhesive property.

Pin On Disk Test analysis:

For sliding application, the frictional force should be minimum. Therefore the concept of smaller the best can be adopted for sliding applications. The following results were obtained

The factor C (powder) is having more influence on the frictional force.

The combination A2,B1,C1 will be best suited for sliding application as it has minimum friction.

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