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ANALYSIS AND PREDICTION OF SURFACE ROUGHNESS OF PLASMA SPRAYED MILD STEEL BY APPLICATION OF SOFT COMPUTING

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ABSTRACT

In many structural applications plasma spray technique has becomes a popular technique because its capability to produce required surface properties. This paper describes about industrial wastes or low grade ore (Flay-ash+ quartz+ illmenite) as the deposition material which is to be coated on Mild Steel substrates. In many cases it is found that surface roughness parameter become crucial for structural modification. To decrease the surface roughness by optimizing other necessary properties, one of the soft computing method i.e. Artificial Neural Network (ANN) technique used. This technique efficiently describe the approximation complexity of inter-relations in between different parameter of atmospheric plasma spray process and helps in saving time & resources for experimental trials for which it is advantageous than all conventional methods. The aim of this investigation is to find out an appropriate input vector set in ANN model. This methodology can provide clear understanding of various co-relationships across multiple scales of length and time which could be essential for improvement of product performance and process. ANN experimental results indicate that the projection network has good generalization capability to optimize the surface roughness. The aim of this article is to find specific parameter set for required surface roughness.

INTRODUCTION

Plasma surfacing is an excellent technology in high-performance coating applications ranging from aerospace industry to biomedical industry (Wixson, 2009; Shahriar, 2009; Wilhelm *et al.*, 2007). Thermal spraying process implements a wide variety of materials (metal, ceramic, alloy and its composite) and processes (Atmospheric plasma spraying, vacuum plasma spraying etc.) for improving surface properties (Pfender, 1987; Deshpande *et al.*, 2004; Davis, 2004). In plasma spraying high frequency arc is ignited between an anode and a tungsten cathode. The gas (i.e., He, H2, N2 or mixtures) flowing through between the electrodes is ionized such that a plasma plume of several centimeters in length develops. The temperature within the plume may reach as high as 16000° K. The spray material in the form of powder particles/wires is injected outside of the gun nozzle into the plasma plume, where it is melted, and accelerated by the gas onto the substrate surface in the form of molten or semi-molten state and very quickly cools to form a high-quality coating (Fauchais, 2004; Moreau *et al.*, 1994).

To increase the of plasma spray technique it is necessary to monitoring the molten feedstock particle characteristics deposited at the substrate surface (Mishra *et al.*, 2006). Surface roughness is also a major part of coating efficiency. Due to multitude of interdependent process parameters results a surface finish; produced by a wide distribution of particle velocities, temperatures, viscosity, substrate impact behavior such as fragmentation and various flattening ratios (i.e. ratio of splat diameter to molten droplet diameter). There are some investigations are done to evaluate surface roughness of plasma spraying by different technique (Reisela *et al.*, 2004; Limin *et al.*, 2002; Gao *et al.*, 2008). By ANN analysis, the interdependency of different parameter involve throughout spray process can study and find out the appropriate parameter set for which surface roughness decreases as well as coating deposition efficiency increases.

Experimental Procedure

Flay-ash premixed with quartz and illuminate mixture taken (weight percentage ratio of 60:20:20) and homogenized by Planetary ball mill for 3 hour. This homogenized mixture used as coating material which is to be coated on Mild Steel substrate of dimension 3 mm thickness and 1 inch diameter. Four different sizes i.e. 40 µm, 60 µm, 80 µm and 100 µm are separated out by the application of sieve. Alumina grit blasting was made at a pressure of 3 kg/cm_2 to create

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surface roughness of about 5Ra, for better bonding. by acetone substrates surface were cleaned which is followed by plasma spraying. The coating process made at the Laser & Plasma Technology Division, BARC, Mumbai. Here 40 KW DC non-transferred arc mode atmospheric plasma spray system used. Input power level varies from 11KW to 21 KW in spray gun. Coating powder material injects externally from the torch nozzle and directed towards the plasma flow. Argon / hydrogen/Nitrogen gas may be used as carrier gas. The major subsystems of the set up include the plasma spraying torch, power supply, powder feeder, and carrier gas supply, torch to substrate surface distance, control console, cooling water and spray booth. A four stage closed loop centrifugal pump water cooling used for retrieving the heat generated during the process, regulated at a pressure of 10kg/cm^2 supply. The specifications of spraying process parameters are given in table 1. Flow rate of plasma gas (argon) and Secondary gas (N_2gas) are kept constant. With increasing power level; Powder feed rate, Powder Size and stand of distance of torch are varied. Measurement of surface roughness done by 'Taylor/Hobson Surtronic 3+' instrument.

Table 1 Experimental plasma sprayed operating parameters

Operating parameters	Parametric variations
Plasma arc current (Amp)	270, 300, 400& 420
Arc voltage (volt)	40,45 & 50
Torch input power (KW)	11,15,18 & 21
Plasma gas(argon) flow rate (IPM)	28
Secondary gas(N_2) flow rate (IPM)	3
Carrier gas(Ar) flow rate (IPM)	12
Powder feed rate (gm/min)	12, 15 & 18
Powder Size (µm)	40, 60, 80 & 100
Torch to base distance/ Stand-of-distance (mm)	100

Artificial Neural Network

A neural network is one type of soft computing model, based on interrelationship between different input and output parameters and learning from data set through iteration, without requiring a prior knowledge on the relationships between the process variables (Friis *et al.*, 2001). This model can able to approximate various nonlinearities in the data series, among other models (Kundas, 2001; Fauchais *et al.,* 2006; etinel *et al.*, 2000) and can give an appropriate optimized data output (here, surface roughness), more quickly (Rao *et al.*, 2000). ANN of simple processing elements (neurons) typically organized by input layers, hidden layers and output layers shown in Figure-1. NEURALNET software used for neural computing which is developed by using back propagation algorithm as the prediction tool for output (coating surface roughness) [18]. For developing an ANN there are no fixed rules, but in general framework it can be followed based on previous successful applications in engineering. The aim of an ANN is to normalize a input-output relationship of the form of ,

$$y^m = f(x^n)$$

Where, x^n is an n-dimensional input vector represents variables $x_1, . , x_i, . , x_n$ and y^m is an m-dimensional output vector represents the resulting variables $y_1,.. , y_i,.. , y_m$. In plasma spray modeling, values of x may be Current, Voltage, stand-of-distance, powder federate and powder size.

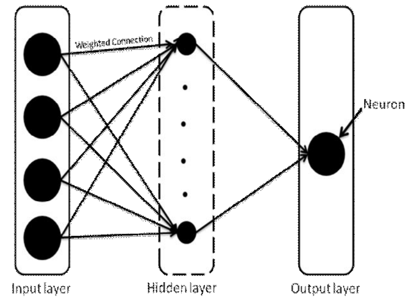


Figure 1 Architecture of Artificial Neural Network

RESULTS AND DISCUSSION

By taking 12 set of parameter in NEURALNET Software, based on least error criterion as shown in Table 2, is selected for training of the input-output data in. The network optimization process (training and testing) is conducted for 1,00,00,000 cycles for which stabilization of the error is obtained. Neuron numbers in the hidden layer is varied and in the optimized structure of the network, this number is 5 for Mild Steel. The three layer network involved is shown in figure-1.

Table 2 ANN Input parameters selected for training

Input Parameters for Training	Values
Error tolerance	0.003
Learning parameter(ß)	0.002
Momentum parameter(α)	0.002
Noise factor (NF)	0.001
Maximum cycles for simulations	1,00,00,000
Slope parameter (£)	0.6
Number of hidden layer neuron	8
Number of input layer neuron (I)	5
Number of output layer neuron (O)	1

Predicted surface roughness compare with experimental results based on different feed rate

In figure 2, there is the comparison plot between experimental data and ANN predicted data. Here it is clear that there is no much error i.e. there is very small deviation of prediction line from that of experimental line. Hence now it is more confident that the future experiment can easily and accurately predicted by changing different input parameters. In this figure surface roughness increase as increase the power level from 11 to 16 KW and then gradually decreases. After 16 KW decrease of roughness is due to more splattering of spray particle on the substrate surface. At higher power level, more is the energy transfer and more is the chance of pore formation due to vaporization of particle which is a demerit of structural materials. Hence there is no need to increase the power level up to highest.

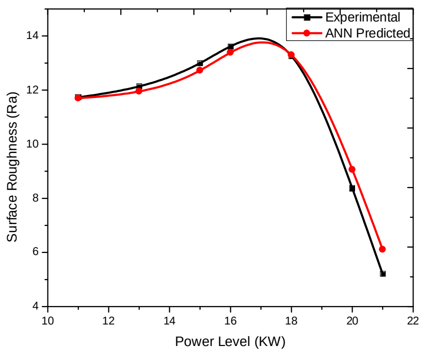
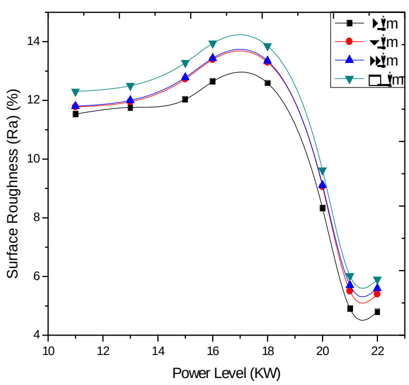


Figure 2 comparison plot between ANN Prediction surface roughness and experimental value at 12 gm/min feed rate (fly-ash+ quartz+ illuminate powder mixture are deposited on mild steel substrates)

Prediction results surface roughness based on variation of powder size

In figure 3 coating surface roughness is plotted against power level by taking different feed rate with constant stand-of-distance=100mm, plasma gas flow rate=28 IPM, secondary gas flow rate=3 IPM & carrier gas flow rate=12 IPM. In figure 3(a), feed rate of 12 gm/min kept constant. Here it is clear that; if lower powder size feeds at a rate of 12 gm/min in plasma,

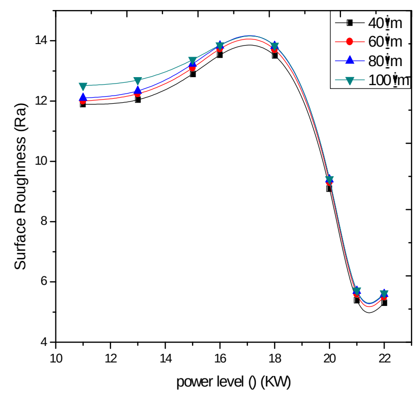


(b)

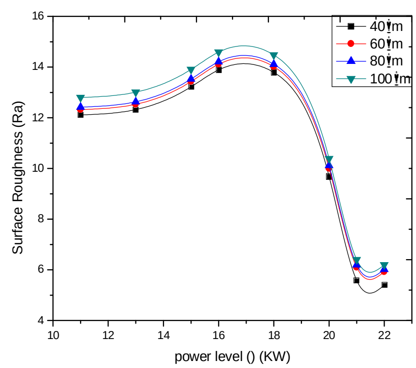
then it gives lower surface roughness than that of higher powder size. But in figure 3(b), there is no significantly change in surface roughness with increase in powder size. Because for this feed rate all powder particles get appropriate energy and splatted on the surface with a better surface finish. So in this case one should have to choose any type of powder size (from 40 µm to 100µm). In figure 3(c), 18 gm/min kept constant. Here 40 µm, 60 µm & 80 µm give nearly same result but powder size of 100 µm deviates more. So in this case higher powder size should not better for spray.

Prediction results of surface roughness based on variation of feed rate

Figure 4(a) shows coating surface roughness graph, in which feed rate increases from 12 gm/min to 18 gm/min at constant powder size=40 µm. In figure 4(b) & 4(c),



(b)



(c)

Figure 3 Dependence of surface roughness with respect to powder size at different feed rate: (a) 12 gm/min feed rate, (b) 15 gm/min feed rat & (c) 18 gm/min feed rate.

there are similar result obtained. In these case 12 gm/min & 15 gm/min is preferable for 60 µm to 80 µm range powder size. In figure 4(d), for 15 gm/min & 18 gm/min feed rate surface roughness nearly same. So for lower powder size smaller than 18gm/min is preferable for spraying. In all plots of figure 4, as the power level increases, all ANN result comes to give nearly same value. Because here higher energy transformation occurs at higher power level and fully molten powder impacts on the substrate surface to give better splats.

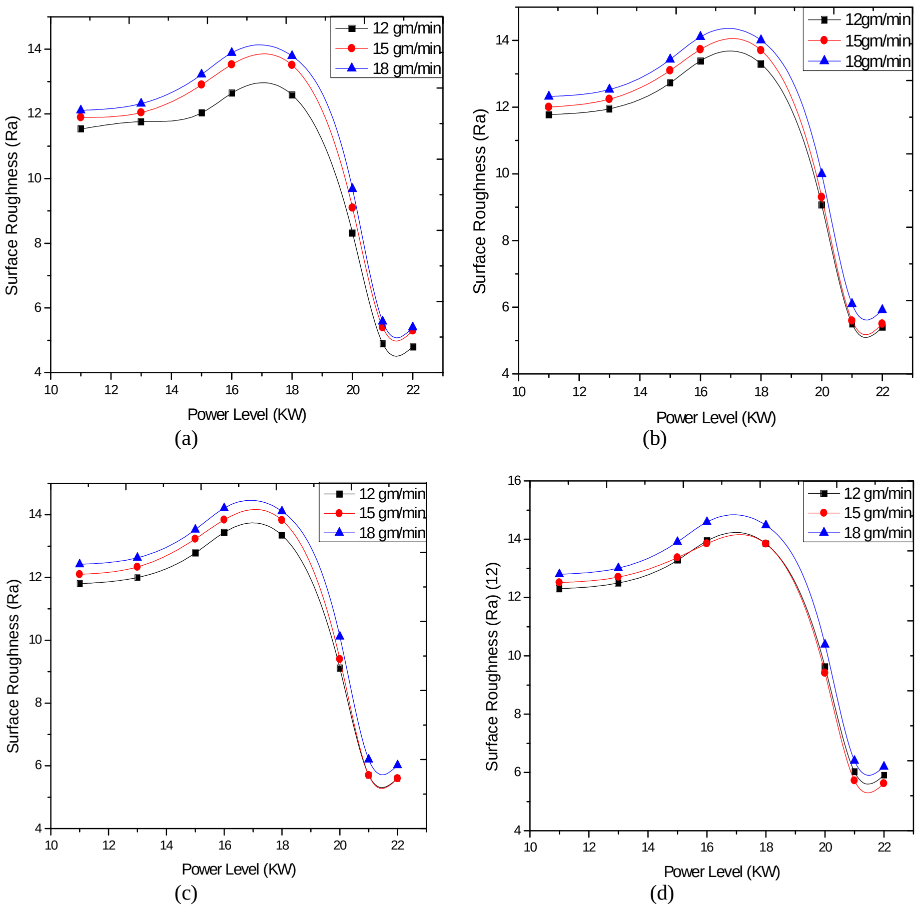


Figure 4 Dependence of surface roughness with respect to feed rate at different powder size: (a) 40 µm, (b) 60 µm, (c) 80 µm and (d) 100 µm.

CONCLUSIONS

The results of surface roughness indicate that neural networks can yield fairly accurate results and can be used as a practical tool in plasma spray manufacturing process. Due to the parallel mechanism, once an ANN is trained, it can provide the ability to solve the mapping problems much faster than conventional methods. In this investigation it is found that for higher feed rate, lower powder size is better for plasma spraying.

In structural engineering aspects, neural networks are expected to progress all methods in term of practicality & effectiveness. Furthermore investigations are developing to generate hybrid neural network technique for producing more accuracy of result.

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