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ANN ANALYSIS OF WEAR BEHAVIOUR OF PLASMA SPRAYED IRON ALUMINIDE COATING

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ABSTRACT

Intermetallic compounds find extensive use in high temperature structural applications. The Fe_3Al based intermetallic alloys offer unique benefits of excellent oxidation and sulfidation resistance at a potential cost lower than many stainless steels. Plasma spraying is considered as a non-linear problem with respect to its variables: either materials or operating conditions. To obtain functional coating exhibiting selected in-service properties, combinations of processing parameters have to be planned. These combinations differ by their influence on the coating properties and characteristics. To control the spraying process, one must recognize the parameter interdependencies, correlations and individual effects on coating characteristics. This paper proposes a mathematical technique based on neural computations to study the effects of process variables on the wear behavior of iron-aluminide coatings made by plasma spraying. ANNs are excellent tools for complex processes that have many variables and complex interactions. The analysis is based on an Artificial Neural Network (ANN) taking into account training and test procedure to predict the dependence of erosion wear behavior on angle of impact and velocity of erodent. This technique helps in saving time and resources for experimental trials.

Keywords: Plasma Spraying, Iron aluminide coating, Solid particle erosion, Neural Network.

1.INTRODUCTION

Fe-Al is currently of commercial interest because of its excellent oxidation resistance, retention of good strength to intermediate temperatures and its low density. The mechanical behavior of Fe-Al depends strongly on both temperature and Fe : Al ratio. These alloys have potential demand in aerospace industry and other high performance applications [1, 2]. In thermal spray applications, iron aluminides and their derivative alloys are used as bond coat materials, where their function is to minimize the thermo-mechanical stresses at the substrate-coating interface and also to promote coating adhesion[3]. The coefficient of thermal expansion of these alloys is intermediate between those of ceramics and metals and therefore can take care of interface stresses. Iron pre-mixed with Aluminium powder is deposited on mild steel substances by atmospheric plasma spraying at various operating power level. The coatings are subjected to erosion wear test. Solid particle erosion is a process where particles strike against a surface and cause material loss. During flight, a particle carries momentum and kinetic energy, which is dissipated during impact due to its interaction with a target surface. In case of plasma spray coatings encountering such situations, no specific model has been developed and thus the study of the erosion behavior has been based on mostly experiment data [4]. Solid particle erosion is considered as a non linear process with respect to its variables: either materials or operating conditions. To obtain the best functional output coatings exhibiting selected in-service properties and the right combinations of operating parameters are to be known. These combinations normally differ by their influence on the erosion wear rate or coating mass loss. In order to control the wear loss in such a process one of the challenges is to recognize parameter interdependencies, co relations and there individual effects on wear. A robust methodology is often needed to study these interrelated effects. In this work, a statistical method, responding to the previous constraints, is implemented to correlate the processing parameters to the coating properties .This methodology is based on Artificial Neural Networks (ANN),which is a technique that involves database training to predict property-parameter evolutions. This section presents the database construction, implementation protocol and a set of predicted results related to the coating erosion rate. Neural networks have provided a means of successfully controlling complex processes in manufacturing industries [5-9]. The details of this methodology are described by Rajesekaran and Pai [10].

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2. EXPERIMENTAL DETAILS

2.1 Coating Deposition

Iron and aluminum powders of size range (40-90) µm are taken and were mixed thoroughly in a planetary ball mill to get homogeneous mixture. This mixture is sprayed on mild steel substrates of dimensions 50×20×3 mm. Spraying is done by using a 40 kW APS (atmospheric plasma spray) system in the thermal plasma laboratory(thermal plasma section, L&PTD, BARC, Bombay). The plasma torch input power is varied from 11 to 21 kW by controlling the gas flow rate, plasma arc current and the arc voltage.

2.2 Erosion Test

Solid particle erosion is usually simulated in laboratory by one of two methods. The 'sand blast' method, where particles are carried in an air flow and impacted onto a stationary target and the 'whirling arm' method , where the target is spun through a chamber of falling particles. In the present investigation, an erosion apparatus (self-made) of the 'sand blast' type is used. It is capable of creating highly reproducible erosive situations over a wide range of particle sizes, velocities, particles fluxes and incidence angles, in order to generate quantitative data on materials and to study the mechanisms of damage. The test is conducted as per ASTM G76 standards.

In this work, room temperature solid particle(sand) erosion test on mild steel substrate coated with iron aluminide as feed materials(at 18kW) is carried out. The coating deposited at18 kW power level is eroded at 30° and 90°angle at SOD of 200mm. 400 µm size dry silica sand particles are used as erodent with different velocities i.e. of 32m/sec, 45m/sec , 58m/sec and at pressures of 4kgf/cm^2,5.5kgf/cm^2,6.5kgf/cm^2 with feed rate 50gm/min, 58gm/min, 62gm/min. Amount of wear is determined on 'mass loss' basis. It is done by measuring the weight change of the sample at regular intervals in the test duration. A precision electronic balance with + 0.01 mg accuracy is used for weighing. Erosion rate, defined as the coating mass loss per unit erodent mass (gm/gm) is calculated. The erosion rates are calculated at different velocities and impingement angles.

3. ARTIFICIAL NEURAL NETWORK (ANN) ANALYSIS

Plasma spraying is considered as a non-linear problem with respect to its variables: either materials or operating conditions. To obtain functional coatings exhibiting selected in-service properties, combinations of processing parameters have to be planned. These combinations differ by their influence on the coating properties and characteristics. In order to control the spraying process, one of the challenges nowadays is to recognize parameter interdependencies, correlations and individual effects on coating characteristics. Therefore a robust methodology is needed to study these interrelated effects. In this work, a statistical method, responding to the previous constraints, is implemented to correlate the processing parameters to the coating properties. This methodology is based on artificial neural networks (ANN), which is a technique that involves database training to predict property-parameter evolutions. This section presents the database construction, implementation protocol and a set of predicted results related to the coating erosion wear. The details of this methodology are described by Rajasekaran and Pai [10].

4.NEURAL NETWORK MODEL: Development and Implementation

An ANN is a computational system that simulates the microstructure (neurons) of biological nervous system. The most basic components of ANN are modeled after the structure of brain. Inspired by these biological neurons, ANN is composed of simple elements operating in parallel. It is the simple clustering of the primitive artificial neurons. This clustering occurs by creating layers, which are then connected to one another. The multilayered neural network which has been utilized in the most of the research works for material science, reviewed by Zhang and Friedrich [11]. A software package NEURALNET for neural computing developed by Rao and Rao [12] using back propagation algorithm is used as the prediction of coating erosion wear rate impact velocity and at different impact angles.

5. ANN Prediction of Erosion Wear Rate

The prediction neural network was tested with four data sets from the original process data. Each data set contained inputs such as impact angle and impact velocity and an output value i.e. erosion wear rate was returned by the network. As further evidence of the effectiveness of the model, an arbitrary set of inputs is used in the prediction network. Results are compared to experimental sets that may or may not be considered in the training or in the test procedures. Fig.1, Fig.2 represent the comparison of predicted output values for erosion wear rate of Iron aluminide coating coated at 18 kW power level with those obtained experimentally with impact velocity of the erodent at different impact angles i.e. 30^0 and 90^0 respectively for 6 minute time interval at SOD of 200mm.

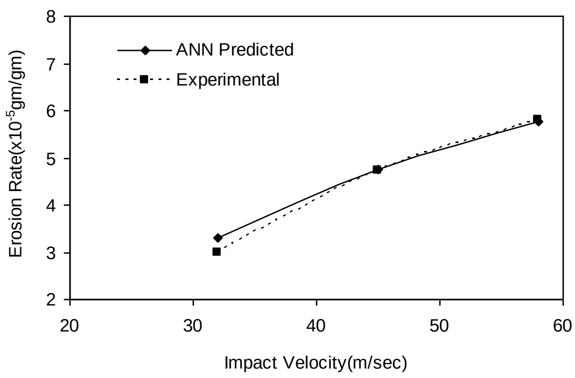

Fig. 1 Comparison plot for predicted and experimental values of coating erosion wear rate (impact angle 30^0, time of exposure 6 min, SOD 200mm)

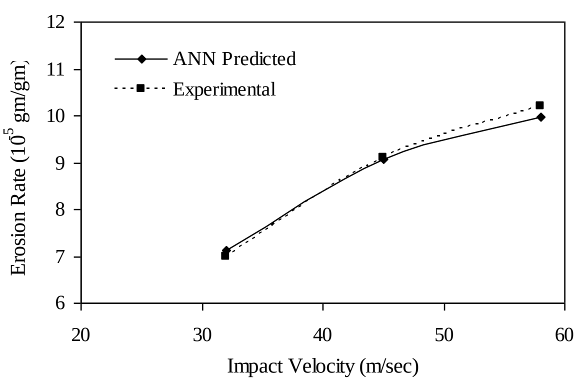

Fig. 2 Comparison plot for predicted and experimental values of coating erosion wear rate (impact angle 90^0, time of exposure 6 min, SOD 200mm)

It is interesting to note that the predictive results show good agreement with experimental sets realized after having generalizing the ANN structures. The optimized ANN structure further permits to study quantitatively the effect of the considered impact velocity. The range of the chosen parameter can be larger than the actual experimental limits, thus offering the possibility to use the generalization property of ANN in a large parameter space. In the present investigation, this possibility was explored by selecting the impact velocity in a range from 20 to 70 m/sec for 30^0,90^0 and a set of prediction for erosion wear rate is evolved. Fig.3, illustrates the predicted evolution of erosion wear rate of iron aluminide coatings on mild steel substrates with the impact velocity.

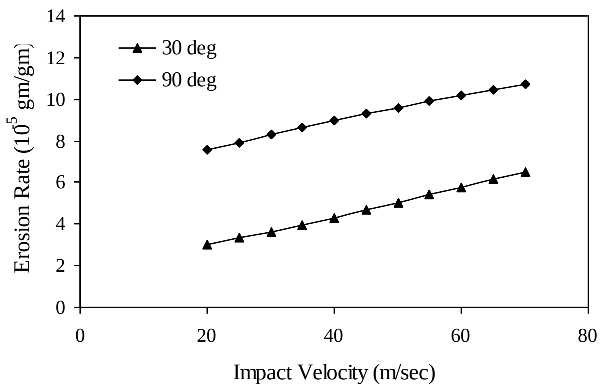

Fig.3 Predicted erosion wear rate at different impact velocities
at impact angles of 30^0,90^0 for 6 minute time of exposure

From the figure it can be seen that, with increasing velocity of impact, erosion rate increases and is different for different inclination angles. It is obvious that, with increasing velocity the particles will have high kinetic energy which transmitted at impact and hence remove more particles from the impacted surface. It is maximum at 90^0 angle.

In the present investigation, this possibility was explored by selecting the impact angle in a range from 10^0 to 90^0 angle for velocities 32m/sec, 45m/sec, 58m/sec and a set of prediction for erosion wear rate is evolved. Fig.4 illustrates the predicted evolution of erosion wear rate of iron aluminide coatings on mild steel substrates with the impact angle.

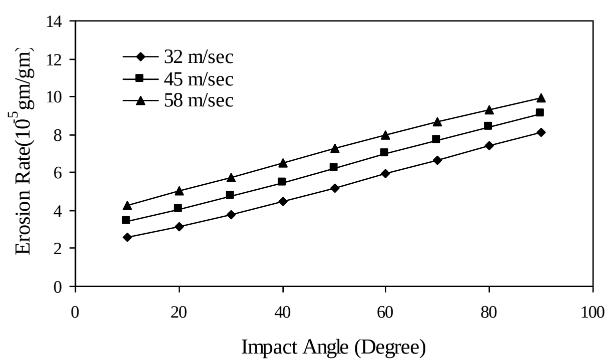

Fig.4 Predicted erosion wear rate at different impact angles for 6 minute exposure time

From the above figure it is found that, with increasing impact angle and velocity of impact erosion rate increases.

6. CONCLUSIONS

Iron aluminide can be used for depositing plasma spray coatings on metals. The coating sustains erosion by solid particle impingement substantially and there fore iron aluminide can be considered as a potential coating material suitable for various tribological applications. Erosion wear behaviour is one of the main requirements of the coatings developed by plasma spraying for recommending specific application. In order to achieve tailored erosion wear rate accurately and repeatedly, the influence of the process parameters are to be controlled accordingly. Neural computation can be gainfully employed as a tool to analyze, optimize and predict the erosion behavior of the coatings purpose. The simulation can be extended to a parameter space larger than experimentation domain.

7.REFFERENCES

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