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# Prediction of Erosion Behaviour of Plasma Sprayed Fly Ash Coatings using Neural Network

**Alok Satpathy, S. C. Mishra, Rojaleena Das, S. S. Mishra***
National Institute of Technology, Rourkela
* Institute of Technical Education and Research, Bhubaneswar
**P. V. Ananthapadmanabhan and K. P. Sreekumar**
Laser and Plasma Technology Division, B.A.R.C. Mumbai
E-mail: aloksatapathy@rediffmail.com

## Abstract

This work reports the implementation of artificial neural networks (ANN) for analysis and prediction of wear behaviour of plasma sprayed fly ash coatings. ANNs are excellent tools for complex processes that have many variables and complex interactions. Solid particle erosion wear is such a process. The results of erosion tests conducted under various test conditions on coated samples constitute the database for the neural computation. The analysis was based on an Artificial Neural Network (ANN) taking into account training and test procedures to predict the dependence of erosion behaviour on exposure time and angle of impact of erodent. This study pointed out primarily that erosion rate of coating is largely sensitive to these parameters. The predictions for a range larger than the experimental domain are made with an optimized neural network structure. This technique helps in saving time and resources for experimental trials.

**Keywords :** fly ash; plasma spraying; solid particle erosion; neural network.

## 1. Introduction

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 on the target surface. In case of plasma spray coatings encountering such situations, no specific model has been developed and thus the study of the erosion behaviour has been based on mostly experiment data [1]. 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 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, correlations and their 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. Artificial neural networks (ANNs) are excellent tools for complex manufacturing processes that have many variables and complex interactions. Neural networks have provided a means of successfully controlling complex processes in manufacturing industries [2 - 6]. The details of this methodology are described by Rajasekaran and Pai [7].

## 2. ANN 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 the brain. Inspired by these biological neurons, ANN is composed of simple elements operating in parallel. ANN is the simple clustering of the primitive artificial neurons. This clustering occurs by creating layers, which are then connected to one another. How these layers connect may also vary. Basically, all ANN have a similar structure of topology. Some of the neurons interface the real world to receive its input, and other neurons provide the real world with the network's output. All the rest of the neurons are hidden from view. The multilayered neural network which has been utilized in the most of the research works for materials science, reviewed by Zhang and Friedrich [8]. A software package NEURALNET for neural computing developed by Rao and Rao [9] using back propagation algorithm is used as the prediction tool for coating deposition efficiency at different operating power levels.

## 3. ANN Prediction of Erosion Wear

The prediction neural network was tested with twelve data sets from the original process data. Each data set contained inputs such as stand off distance, angle of impact, exposure time and erodent size and an output value i.e. erosion rate or the coating mass loss 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 were compared to experimental sets that may or may not be considered in the training or in the test procedures. Fig. 1 presents the comparison of predicted output values for erosion rate with those obtained experimentally.

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 each of the considered input parameter. The range of any 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 has been explored by selecting the exposure time from 2 min to 24 min and sets of predictions for erosion rate are evolved. Fig. 2 illustrates the predicted evolution of erosion rate with respect to the time for which the coating would be exposed to erodent stream.

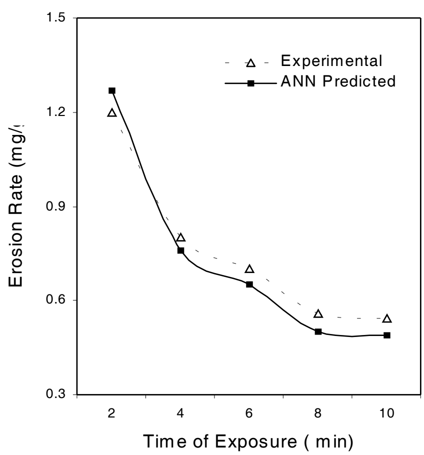


**Fig. 1. Comparison plot for predicted values of wear rate for $30^0$ angle of impact.**

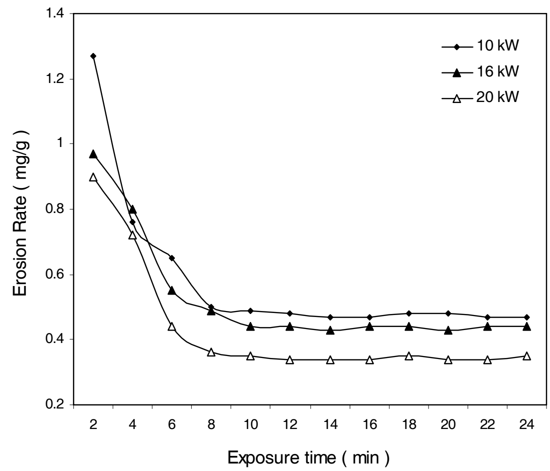


**Fig. 2. Predicted coating erosion rate and experimental for different exposure time**

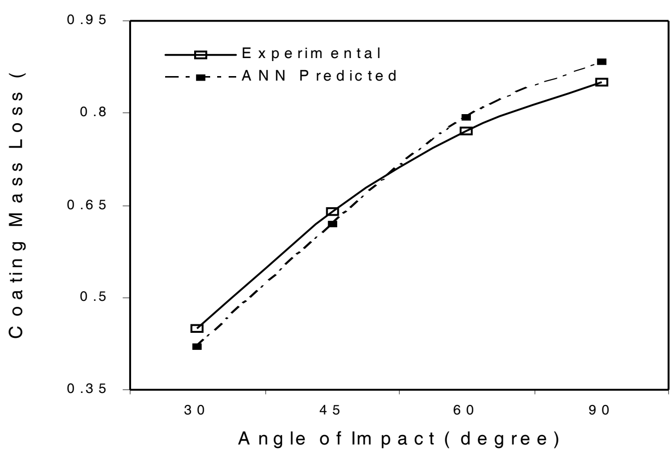


**Fig. 3. Predicted coating mass loss for different angle of impact**

The decrease in the wear rate of various plasma sprayed coatings with erosion time (or erodent dose) has been reported earlier by many investigators. It has been shown that, the incremental erosion rate curves of brittle materials start with a high rate at the first measurable amount of erosion and then decreases to a much lower steady state value. In the present work also, this trend is found in case of the coatings subjected to erosion test at various impact angles. This can be attributed to the fact that the fine protrusions on the coating parts are relatively loose and can be removed with less energy than what would be necessary to remove a similar part from the bulk of the coating. Consequently, the initial wear rate is high. With increasing exposure time the rate of wear starts decreasing and in the transient erosion regime, a sharp drop in the wear rate is obtained. As the coating surface gradually gets smoothened, the rate of erosion becomes steady.

This variation of erosion wear loss confirms that the angle at which the stream of solid particles impinges the coating surface influences the rate at which the material is removed. It further suggests that, this dependency is also influenced by the nature of the coating material. The angle of impact determines the relative magnitude of the two components of the impact velocity namely, the component normal to the surface and parallel to the surface. The normal component will determine how long the impact will last (i.e. contact time) and the load. The product of this contact time and the tangential (parallel) velocity component determines the amount of sliding that takes place. The tangential velocity component also provides a shear loading to the surface, which is in addition to the normal load that the normal velocity component causes. Hence as this angle changes the amount of sliding that takes place also changes as does the nature and magnitude of the stress system. Both of these aspects influence the way a coating wears. These changes imply that different types of material would exhibit different angular dependency.

## 4. Conclusions

Fly ash, the industrial waste can be used for depositing plasma spray coatings on metals. The coating sustains erosion by solid particle impingement substantially and therefore fly ash can be considered as a potential coating material suitable for various tribological applications. Neural computation can be gainfully employed to analyze, optimize and predict the erosion wear behaviour of these coatings.

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