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Estimation of Vision Parameters of Surface Roughness and Wire Wear in Wire-EDM of Al-10 wt.% Si3N4 MMC Material using ANN

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Abstract— **Present study outlines the estimation of machine vision parameters of surface roughness and wire wear in wire EDM of Al-10 wt. % Si_3N_4 metal matrix composite material using artificial neural network. Al-10wt. %Si_3N_4 material was selected as a work material. WEDM Parameters such as pulse-on time, pulse-off time, current and bed speed were considered. This work material was machined by varying pulse-on time and bed speed. The images of wire electrode and machined surface specimens were acquired using the machine vision system. The wire wear in WEDM and surface roughness (Ga) of a machined component is measured based on the analysis of the distribution of light intensity. The Artificial Neural Network is used to study and predict the machining responses. Input data are fed into the neural network and corresponding weights and bias are extracted. Then weights and bias are integrated in the program which is used to calculate and predict the machining responses. Estimation of machine vision parameters of surface roughness and electrode wear were obtained by using ANN for various cutting conditions. From the results it was observed that, measured and estimated machine vision parameters of surface roughness and electrode wear values were correlates well with ANN. From the predicted values, wire electrode status monitoring in WEDM can be successfully accomplished by analyzing the surface image data.**

Keywords— WEDM, Machine vision, MMC, ANN

I. INTRODUCTION

The need for composite material has increased in various sectors due to the technological developments and requirement of complex shapes in manufacturing sectors. Metal matrix composites are the most widely used composite materials. Wire cut EDM is quite efficient for machining such materials and it provides good solution for machining harder materials with complex shapes. Machine Vision system is a subfield of many engineering disciplines viz., computer science, industrial automation, optics and mechanical engineering. Machine vision system is the application of image processing to manufacturing industries. Manufacturer's favors vision system for visual inspections that require high-speed, high-magnification, 24-hour operation and repeatability of measurements. Under a given cutting conditions precise estimation of cutting tool life is one of the important issues in the metal cutting process. An integrated "Intelligent Sensor System" consisting of signal conditioning devices, signal processing algorithms, sensing elements, interpretation and decision makes procedure. In recent years, image analysis is easier and more flexible due to the advent of high-speed digital computers and vision systems. Stylus instruments measure surface roughness along a single line where as computer vision systems have the advantage of measuring surface roughness across the area [1]. It was found that vision parameters are affected by the roughness of the surface. For smooth surfaces co-efficient of variance parameter is having more correlation than other parameters and the vision parameter, arithmetic gray level average (Ga) is having better correlation for rough surfaces [2]. The acquired images from modern cameras may be contaminated due to the various noise sources and very low intensity. Hence, to evaluate the roughness of the machined surfaces the evolvable hardware technique can be used. Further study is to be focused on artificial neural network (ANN) to estimate surface roughness parameters using image features as input [3].

II. EXPERIMENTAL WORK

The experiments were conducted on CONCORD DK7720C four axes CNC Wire-cut EDM. Wire electrode, a servo control system, a work table, dielectric supply system and a power supply are the basic parts of the Wire-cut EDM. Based on the material and height of the components the input parameters are selected in CONCORD DK7720C by the operator. The Wire-cut EDM has several special features. Unlike other Wire-cut EDM's, it uses the reusable wire technology. i.e., wire can't be thrown out once used; instead it is reused adopting the re-looping wire technology. The experimental set-up is illustrated in the Fig. 1. and Fig. 2.

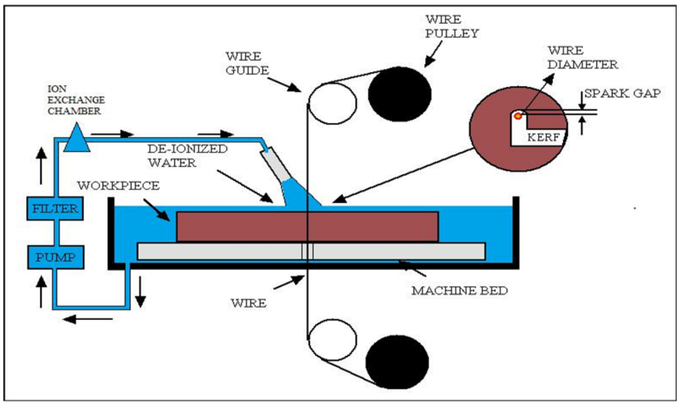

Fig.1.Wire Electro Discharge Machining Process

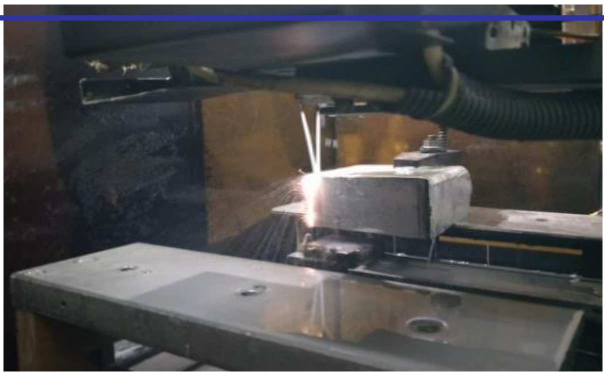

Fig.2.Experimental Setup

Table 1. Parameters used in experiments.

Control factors	Level		
	I	II	III
Pulse-on time	20	24	28
Pulse-off time	5	6	7
Current	4	5	6
Bed Speed	30	35	40

The control factors and fixed parameters selected are as listed in Table 1.The gap between wire and work piece is 0.02 mm and is constantly maintained by a computer-controlled positioning system. Molybdenum wire having diameter of 0.18 mm was used as an electrode. Experiments were conducted on machining of Al-10wt.%Si_3N_4 composite material. The input parameters were pulse-on time, pulse-off time, bed speed and current. Response variables were wire electrode status and Surface roughness. Surface roughness and wire electrode status were measured using machine vision system, then it is compared with the surfcom flex 50-A and digital micrometer; which are conventional measuring instruments for measuring Surface roughness and wire electrode status respectively.

A. Surface Roughness Measurement

In the present work, based on the analysis of the distribution of light intensity on a rough surface, surface roughness can be measured. Experiments were carried out to know the effectiveness of vision based parameters for measurement of surface roughness. Based on DoE technique and by using WEDM different roughness values are obtained. The stylus parameter average surface roughness (Ra) of these specimens was measured using stylus instrument. A good florescent light source was used to illuminate the work piece rough surface while conducting the machine vision experiments. Nikon D-90 camera was used to capture an image of the reflected light.

Captured image was analyzed using a program developed in matlab, using this program vision based parameter was computed from the stored surface image. To identify whether the vision based parameters are sufficient in themselves to characterize a surface roughness, average surface roughness (Ra) values were then compared with vision based parameter (Ga).

It was assumed that the peaks on any surface will reflect more light than its surroundings and the parameter is calculated based on the distribution of these peaks. Regional maximum approach method is based on the relative gray level intensity of the each pixel with its surrounding pixels. The gray image is converted into binary image by assigning “1s” for pixel having more intensity values than its surrounding pixels in the cell and remaining all into “0s”.

Vision-Based Parameters Computed

The arithmetic average of the gray level intensity matrix was computed using

$$G_a = \frac{1}{N}\sum_{x=0}^{255}(F_i X_i) \quad (1)$$

Where N is the total number of pixels in the distribution, F_i is the number of pixels at grey-level X_i, and X_i are the grey levels (i =0, 1, 2, 3, 4 . . . 255).

Machine vision approach was used for work piece status evaluation and monitoring of Wire-cut EDM. Experiments have been conducted to monitor the changing of work piece surface texture caused by the increased of electrode wear state, through the variation of images of work piece in machining, under different cutting conditions. Image processing analysis was carried out on images acquired using high resolution digital camera which is fitted with extension tubes to give a better magnification. Images were processed at 8 bit grey-level intensity resolution.

The histogram distributions of an illuminated region of interest (ROI) from WEDM surface images were analyzed for grey level intensity distribution etc. They are recognized as descriptors of image properties such as contrast, brightness, etc. In order to establish noticeable differences between these textures, ROIs were selected from initial work piece surface and final WEDM surface images. This data was used to explore the properties of typical image intensity distributions.

The objective of the present work is to evaluate the effectiveness of machine vision system for measuring the surface roughness of machined component and based on textural information of machined component, electrode condition can be assessed.

B. Wire Electrode status visualization and monitoring

An image of the wire electrode was captured using Nikon D-90 high resolution digital camera. Program written in Matlab software using image processing toolbox was used for analysis of the captured image. Vision parameter of electrode wear was computed from the stored image using this program. The wire wear feature was extracted from selected ROI of wire before machining and wire after machining. Vision parameter was then compared with the electrode wear measured using digital micrometer to identify whether the optical parameters are sufficient in themselves to characterize an electrode wear.

III. RESULTS AND DISCUSSION

Vision parameters of workpiece Surface Roughness (SR) and Electrode Wear (EW) models were defined utilizing feed forward neural networks based on back propagation algorithm. For the designed neural network, the cutting test data were provided in order to train, validate and test them. Several configurations of networks, characterized by different number of hidden layers and number of neurons in the hidden layers, were trained for carrying out the best arrangement for the status parameters prediction, in terms of resulting errors. The Neural Network Toolbox of Matlab software was used for developing artificial neural network and the Levenberg-Marquardt back propagation algorithm was chosen. The input pattern had to be divided in two sets for training and validating the network. The Matlab toolbox was programmed to divide the input pattern as: the 70% for training the network and the 30% for validating it. After these two first phases, the ANNs giving the lowest MSE were chosen as the right predictive instruments. In particular, vision parameters of workpiece surface finish and electrode status data of experiments were utilized. ANN architecture provided the best results for surface finish and electrode wear prediction. The results of experimental and theoretical analysis are presented in the following graphs so that a clear insight can be obtained about the various signals. Functional relationships between the parameters obtained have been shown to derive a basis for a more detailed analysis. Experiments were done for various cutting conditions. The experimental results are presented below. Fig. 1&2 and Fig. 3&4 shows the ANN estimates of vision parameters of electrode wear and surface finish respectively for different cutting condition.

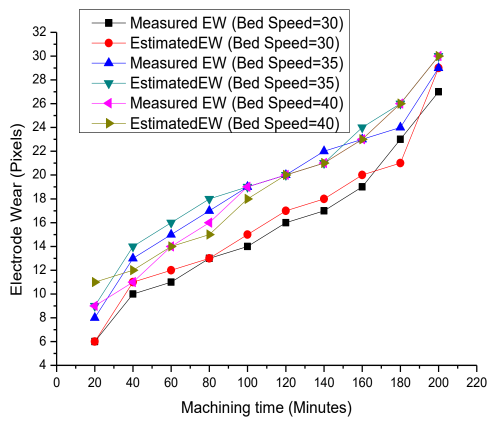

Fig.1. ANN estimates of EW at P-on =20µSec, P-off=5µSec & current=4mA

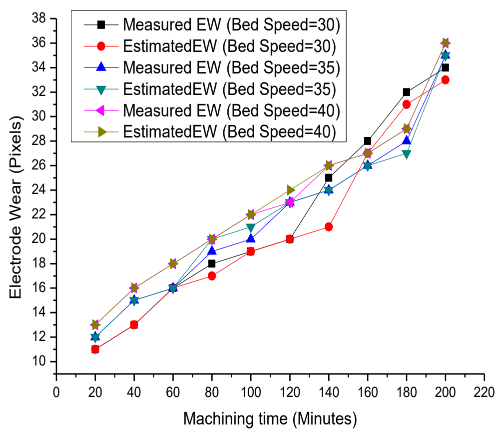

Fig.2. ANN estimates of EW at Pulse-on =28µSec, P-off=5µSec &current=4mA

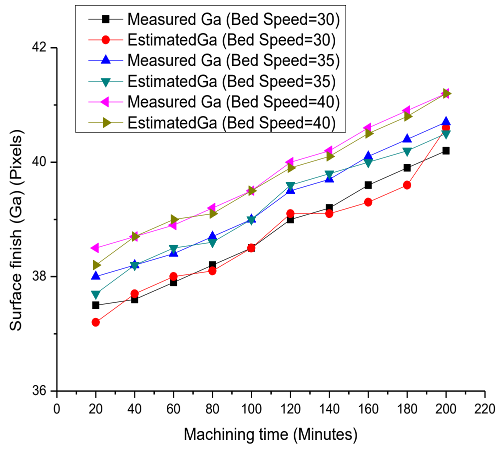

Fig.3. ANN estimates of SR (Ga) at P-on=20µSec, P-off=5µSec & current=4mA

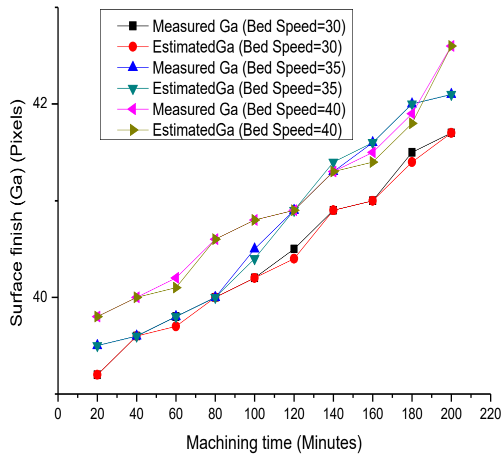

Fig.4. ANN estimates of SR (Ga) at P-on=28µSec, P-off=5µSec & current=4mA

Some established observation from the Estimation by ANN study were found to produce a regression coefficient closer to 1 and mean squared error closer to 0. Hence this particular topology of ANN was found to be feasible. The training and estimation has generated closer outputs. Analyzing the graphs, it was seen that most of the estimates represent the observed trend of machine vision parameters. The trend observed was same with other cutting conditions. Better correlation was obtained at high bed speeds. Under these conditions, there will be a large-scale variation in electrode wear, resulting in more vision values. Due to higher values, correlation may have been better. Similar trend was observed for other cutting conditions.

IV. CONCLUSION

In this paper, a machine vision system has been implemented on Wire EDM machine to measure wire electrode status and surface finish of the workpiece. With the aid of image-processing software, this developed vision system has been well constructed to precisely measure the wire electrode status and surface finish of the workpiece. For real time surface texture condition monitoring with non-contact techniques, the image processing algorithms can be used for enhancing the automation proficiency in unmanned tool

From analysis of results obtained in estimation of vision parameters in machining of Al-10 wt.%Si_3N_4 with molybdenum electrode at different cutting conditions investigated, the following conclusions can be drawn:

- Regression coefficient closer to 1 and mean squared error closer to 0, were found to produce with 4 input parameters, 2 hidden layers and 10 hidden neurons. Hence this particular topology of Artificial Neural Network was found to be feasible.
- The training and estimation have generates closer outputs with 4 input parameters, 2 hidden layers and 10 hidden neurons.
- ANN estimates have good correlation at higher bed speed.
- The use of vision signal of electrode status and workpiece surface finish has proved to be more efficient than conventional monitoring.

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