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Study of Surface Roughness and AE Signals while Machining Titanium Grade-2 Material using ANN in WEDM

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Abstract

Wire Electrical Discharge Machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes. It is widely recognized that Acoustic Emission (AE) is gaining ground as a monitoring method for health diagnosis on rotating machinery. The advantage of AE monitoring over vibration monitoring is that the AE monitoring can detect the growth of subsurface cracks whereas the vibration monitoring can detect defects only when they appear on the surface. This study outlines the development of model and its application to estimation of machining performances using Artificial Neural Network (ANN). Each experiment has been performed under different process parameters of pulse-on time, pulse-off time, current and bed speed. Among different process parameters voltage and flush rate were kept constant. Molybdenum wire having diameter of 0.18 mm was used as an electrode. Estimation and comparison of responses like surface roughness and AE signals was carried out using ANN.

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Keywords: WEDM; AE; ANN.

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1. Introduction

The wire-cut type of machine arose in the 1960s for the purpose of making of tools (dies) from hardened steel. The tool electrode in WEDM is simply a wire. To avoid the erosion of material from the wire causing it to break, the wire is wound between two spools so that the active part of the wire is constantly changing. The earliest Numerical Controlled (NC) machines were conversions of punched-tape vertical milling machines. WEDM is an alternative competitive process to manufacture complex part geometries.

The present work was carried out for a detailed study on estimation of surface roughness and AE parameters of Titanium Grade-2 material in WEDM. Process parameters such as pulse-on time, pulse off time, current and bed speed were varied. The measured surface roughness and AE parameters namely signal strength and absolute energy was compared with predicted values using ANN. In the past, researchers have investigated workpiece productivity & integrity when Udimet 720 nickel based super alloy and Ti-6Al-2Sn- 4Zr-6Mo titanium alloy, were machined using Cu core coated wires (ZnCu50 and Zn rich brass) in WEDM. It was seen that an increase in productivity of ~40% for Udimet 720 and ~70% for Ti6246 was possible when replacing standard uncoated brass wire with diffusion annealed coated wires under the same operating parameters. This could be further raised to 90% for Ti6246 and 60% for Udimet 720 by increasing pulse on-time while still maintaining an acceptable level of surface roughness [1]. The development of model and its application to optimize WEDM machining parameters using the Taguchi's technique which is based on the robust design. Experimentation was performed as per Taguchi's L'_{16} orthogonal array. Each experiment has been performed under different cutting conditions of pulse-on, pulse-off, current, and bed speed [2]. The Powder Mixed Electrical Discharge Machining (PMEDM) of γ-TiAl by means of different powders such as aluminum, chrome, silicon carbide, graphite and iron is performed to investigate the output characteristics of surface roughness and topography, Material Removal Rate (MRR), electrochemical corrosion resistance of machined samples and also the machined surfaces are investigated by means of EDS and XRD analyses. Secondly after selection the aluminum powder as the most appropriate kind of powder, the current, pulse on time, powder size and powder concentration are changed in different levels for overall comparison between EDM and PMEDM output characteristics. In the first setting of input machining parameters, aluminum powder improves the surface roughness of TiAl sample about 32% comparing with EDM case and also aluminum particles with the size of 2 μm, inthe second setting of input parameters lead to 54% enhancement of MRR comparing with EDM case [3]. The effect of seven process parameters including pulse width, servo reference voltage, pulse current, and wire tension on process performance parameters was investigated while machining titanium alloy and it was found that surface roughness increased with pulse width and decrease with pulse interval [4]. Three responses namely accuracy, surface roughness, volumetric material removal rate have been considered for each experiment and estimated using Multiple Regression Analysis (MRA), Group Method of Data Handling Technique (GMDH) and ANN. ANN function gave better prediction than MRA and GMDH [5].

2. EXPERIMENTAL WORK

The experiments were performed on CONCORD DK7720C four axes CNC WED machine. The basic parts of the WED machine consist of a wire electrode, a work table, a servo control system, a power supply and dielectric supply system. The CONCORD DK7720C allows the operator to choose input parameters according to the material and height of the work piece. The WED machine has several special features. Unlike other WED machines, 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. To avoid the erosion of wire from the material causing it to break, thus the wire is constantly changing before each experiment. The experimental set-up for the data acquisition is illustrated in the Fig. 1. The WEDM process generally consists of several stages, a rough cut phase, a rough cut with finishing stage, and a finishing stage. But in this WED machine only one pass is used. 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. The experiments were conducted by varying the process parameters like pulse on, pulse off, current and bed-speed using 'L_{16}' orthogonal array.

Fig. 1. Experimental Set-up during machining

3. Results and Discussions

3.1. Artificial Neural Network (ANN)

A neural network is an artificial representation of human brain that tries to simulate its learning process. An Artificial Neural Network (ANN) is often called as neural network. ANN is an interconnected group of artificial neurons that uses a mathematical model or computational models for information processing based on a connectionist approach to computation. The artificial neural networks are made of interconnecting neurons which may share some properties of biological neurons. Various input to the neurons are represented by 'X_n'. Each of these inputs is multiplied by a connection weighed, represented by 'W_n' and added to the bias 'φ' to compute activation 'a_n' which is converted into the output 'O_n' via transfer function.

$$a_n = W_n X_n T + \varphi$$

$$O_n = f\,(a_n)$$

Initially, an attempt was made to obtain a clear insight involved in the process by plotting measured surface roughness, AE signal strength and AE absolute energy values against machining time.

3.2. Effect of minimum and maximum pulse on and current on signal strength, absolute energy and surface roughness

Fig. 2 shows the surface roughness (Ra) curves for maximum pulse on of 28 µm with the varying in other process parameters. From the Figure, it can be observed that the surface finish deteriorates with the machining time.

Fig. 3 shows the signal strength curves with machining time for maximum current of 6 amps. The plot reveals that during the machining, the signal strength has little higher gradient along with the other parameters.

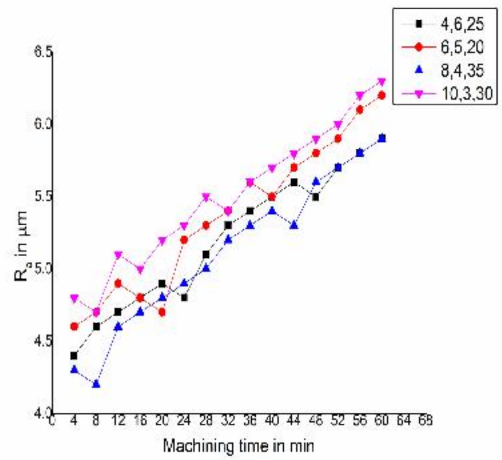

Fig. 2 Measured Surface roughness for different machining time at maximum Pulse on of 28µm

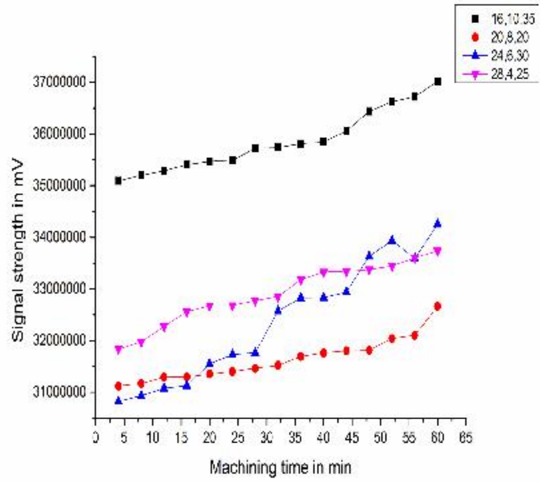

Fig. 3 Measured Signal strength for different machining time at a constant current 6 amps

3.3. ANN Prediction

The prediction of Surface roughness and AE Signals (Signal Strength & Absolute Energy) was carried out using neural network fitting tool (NNFT) for training sets of 50%, 60% and 70% for three neurons. When the training was completed, it is necessary to check the network performance and to determine if any change needs to be made to the training process, network architecture or the datasets. The predicted Surface roughness & AE Signals like signal strength & absolute energy of 70% of the dataset exhibits better correlation with the measured electrode wear than 50% and 60% of the dataset and better Regression co-efficient (R value) was also found at this dataset. Fig 4 & 5 shows the prediction of signal Strength & Surface roughness along with the measured value at pulse on 16 µm, pulse off 4 µm, current 3 amps, bed speed µm/s and at pulse on 24 µm, pulse off 6 µm, current 6 amps, bed speed 30 µm/s respectively at 70% dataset.

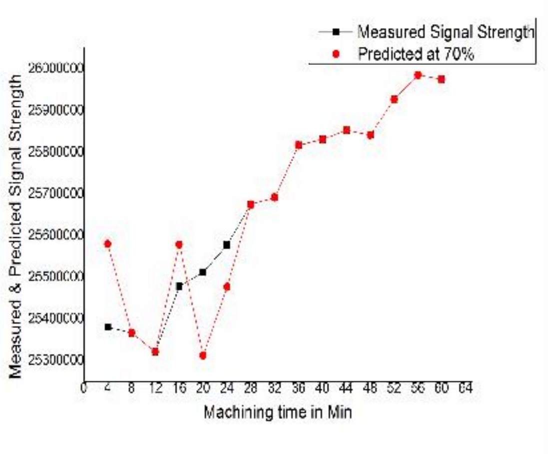

Fig. 4 Measured Signal Strength for different machining time at 70% of dataset

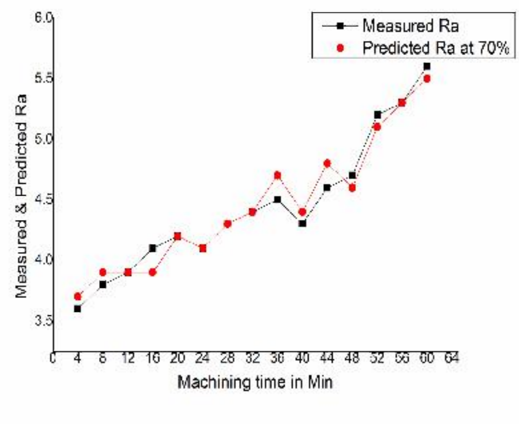

Fig. 5 Measured surface roughness for different machining time at 70% of dataset

4. Conclusion

The roughness plots have increased for maximum cutting condition. Recorded AE parameters (Absolute Energy and signal strength) and measured roughness curves showed a remarkable similarity with the characteristic three distinct phases depicted on both the roughness-time and AE-time plots .ANN was used successfully to predict the Surface roughness & AE signals. Neural network trained with 70% of the data in training set exhibits good prediction results when compared with the 50% and 60% of data in training set with minimum R value.

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