6th International & 27th All India Manufacturing Technology, Design and Research Conference (AIMTDR-2016), December 16-18, 2016 at College of Engineering., Pune, Maharashtra, INDIA.

Machining and Estimation of Surface Roughness and AE Parameters of P20 Material in Wire Electric Discharge Machining using Artificial Neural Network

Prathik Jain S[1], H V Ravindra[2], G V Naveen Prakash[3], G Ugrasen[4]

[1]*Assistant Professor, Department of Aeronautical Engineering, Dayananda Sagar College of Engg., Bengaluru, Karnataka.*

[2]*Professor, Dept. of Mechanical Engg., P.E.S. College of Engg., Mandya, Karnataka*

[3]*Professor, Dept. of Mechanical Engg.,Vidya Vardhaka College of Engg., Mysore, Karnataka*

[4]*Assistant Professor, Dept. of Mechanical Engg., BMS College of Engg., Bangalore, Karnataka*

[1]prathik9@gmail.com
[2]mailhovera@yahoo.com
[3]npgvi@yahoo.co.in
[4]ugrasen.g@gmail.com

***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. Selection of process parameters for obtaining higher cutting efficiency or accuracy in WEDM is still not fully solved, even with most up-to-date CNC wire EDM machine. It is widely recognised 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 machining of P-20 tool steel material using L'16 orthogonal array. P-20 tool steel material is used for various large-size plastic mould, precision plastic mould, car accessories, home appliances and electronic equipment plastic moulds. Each experiment has been performed under different process parameters of pulse-on, pulse-off, 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. Simple functional relationships between the parameters were plotted to arrive at possible information on surface roughness and AE signals. But these simpler methods of analysis did not provide any information about the status of the work material. Thus, there is a requirement for more sophisticated methods that are capable of integrating information from the multiple sensors. Hence, a model and its application for the estimation of surface roughness and AE parameters were developed using Artificial Neural Network (ANN) and estimation of theoretical results and experimental results were compared. Surface roughness and AE parameters prediction was carried out successfully for 50%, 60% and 70% of the training set for P-20 tool steel material using ANN.**

***Keywords*— P-20 tool steel, AE, WEDM, Ra, ANN**

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 P20 tool steel material in WEDM. Process parameters such as pulse-on time, pulse off time, current and bed speed was varied. The measured surface roughness and AE parameters namely signal strength, absolute energy and RMS was compared with predicted values using ANN, and estimation of theoretical results and experimental results were compared. P-20 is used for various large-size plastic mould, precision plastic mould, car accessories, home appliances and electronic equipment plastic moulds. In the past, researchers have investigated the effect of parameters on Metal Removal Rate (MRR) for WEDM using High Strength Low Alloy steel as work piece and brass wire as electrode. HSLA used in cars, trucks, cranes, bridges, roller coasters and other structures that are designed to handle large amounts of stress. It is observed that MRR and surface roughness increases with increase in pulse on time and peak current [1]. Nimonic-90 has been evaluated on wire electrical discharge machining process, cutting speed has been considered as machinability attribute in this work. Influence of WEDM parameters namely discharge current (Ip), pulse on time (Ton), pulse off time (Toff), servo voltage (SV) and wire feed rate (WF) were investigated on cutting speed of Nimonic-90 [2]. One of the main challenges in WEDM is avoiding wire breakage and unstable situations as both phenomena reduce process performance and can cause low quality components. The methodology has been followed as applied to process instability and wire breakage detection in WEDM. First, an acquisition system has been developed aimed at storing an extensive experimental database based on stable and unstable tests. The results of a preliminary analysis of a set of tests have revealed the influence on wire breakage of discharge variables, such as peak current, discharge energy and ignition delay time. Related to these discharge variables, wire breakage indicators have been defined [3]. AE signal as the frame of reference for determining the acoustic time lag, the proof-of-concept of the applications of AE discharge mapping for the respective identification of electrode length and workpiece height in fast-hole EDM and WEDM are presented. Additional work in terms of acquisition and processing of AE signals is warranted to further develop this technology towards its real-time implementation, as well as its extension to sink EDM [4].

Machining of Ti-6Al-4V in Wire EDM was considered using three different machine rates which are 2 mm/min, 4 mm/min and 6 mm/min with constant current (6A). The effects of different process parameters on the kerf width, material removal rate, surface roughness and surface topography are also discussed. The best combination of machining parameter viz. machine feed rate (4 mm/min), wire speed (8 m/min), wire tension (1.4 kg) and voltage (60 V) were identified [5]. A simplistic analytical model is used to evaluate the effectiveness of low frequency workpiece vibration during the micro-EDM drilling of deep micro-holes and experimental investigation to validate the model by studying the effects of workpiece vibration on machining performance, surface quality and dimensional accuracy of the micro-holes [6]. Two modeling approaches, regression and ANN, are applied to predict the minimum Ra value. The results show that regression and ANN models have reduced the minimum Ra value of real experimental data by about 1.57% and 1.05%, respectively [7].The effect of process parameter like Pulse ON time, Pulse OFF time, Voltage, Wire Feed and Wire Tension on MRR, SR, Kerf and Gap current is studied by conducting an experiment. ANN is used for Predict of output parameters of Wire EDM of AISI A2. The training, testing and validation data set are collected by conducting experiment on work piece material AISI A2.It is found that ANN is a powerful tool for data prediction [8].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 Data Handling Technique (GMDH) and ANN. ANN function gave better prediction than MRA and GMDH [9].

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 design of the experiment is as shown in the table1.

Fig. 1. Experimental Set-up during machining

3. RESULT AND DISCUSSIONS

A. Effect of minimum and maximum pulse on time on signal strength, absolute energy, RMS and surface roughness

Fig.2 & Fig 3 shows the surface roughness (Ra) & absolute energy curves for minimum pulse on time of 16μs and maximum pulse on time of 28 μs for P20 tool steel material respectively with varying the other process parameters viz., pulse off time (4µs, 6µs, 8µs, 10µs) current (3amps, 4amps, 5amps, 6amps)bed speed (20 µm/s, 25 µm/s, 30 µm/s, 35 µm/s). From the figure, it can be observed that at higher process parameters surface finish deteriorates and absolute energy has high gradient at lower process parameters.

TABLE 1 EXPERIMENTAL DESIGN

Run	P-on (µs)	P-off (µs)	Current (A)	Bed Speed (µm/s)
1	16	4	3	20
2	16	6	4	25
3	16	8	5	30
4	16	10	6	35
5	20	4	4	30
6	20	6	3	35
7	20	8	6	20
8	20	10	5	25
9	24	4	5	35
10	24	6	6	30
11	24	8	3	25
12	24	10	4	20
13	28	4	6	25
14	28	6	5	20
15	28	8	4	35
16	28	10	3	30

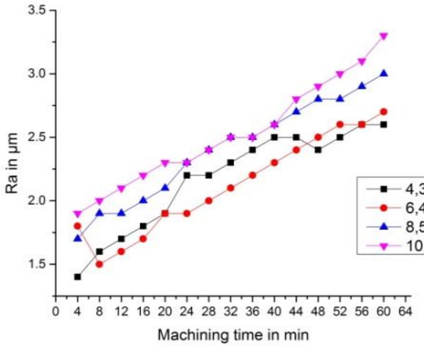

Fig:2 Measured surface roughness for different machining time at minimum Pulse on of 16µs for P20 Tool Steel material

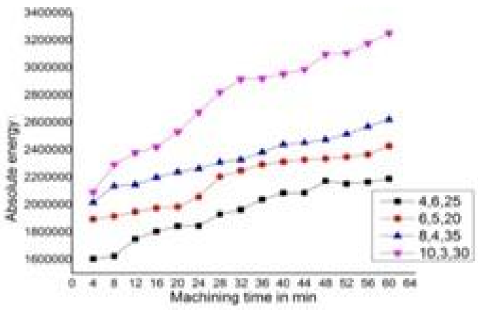

Fig:3 Measured Absolute Energy for different machining time at maximum Pulse on of 28µs for P20 Tool Steel material

B. Effect of minimum and maximum current on signal strength, absolute energy, RMS and surface roughness

Fig.4 & 5 Shows the RMS & Signal strength curves for minimum and maximum current of 3 & 6 amps respectively for P20 tool steel material with varying the other process parameters viz., pulse on time (16 µs, 20 µs, 24 µs, 28 µs) pulse off time (10µs, 8µs, 6µs, 4µs) bed speed (35 µm/s, 20 µm/s, 30 µm/s, 25 µm/s). From the figure it can be observed that higher gradient was found in lower process parameters both for RMS & signal strength.

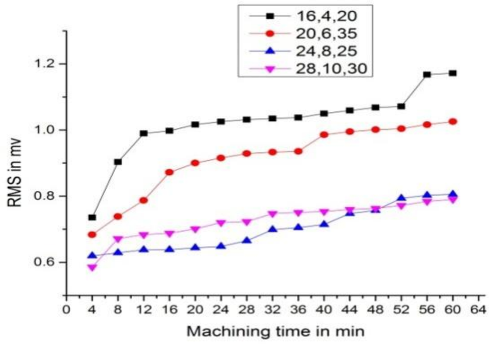

Fig:4 Measured RMS for different machining time at a constant current 3 amps for P20 tool steel material

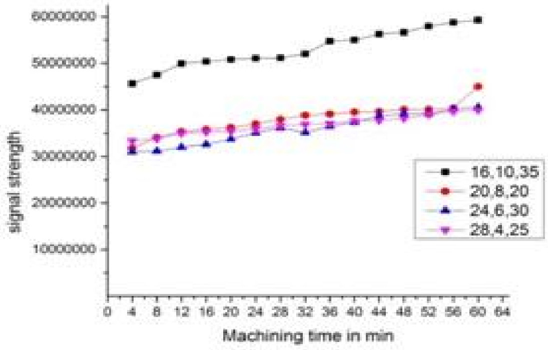

Fig:5 Measured signal strength for different machining time at constant current 6 amps for P20 Tool Steel material

C. ANN Prediction

The prediction of Surface roughness and AE Signals (Signal Strength, Absolute Energy & RMS) 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 & RMS of 70% of the dataset exhibits better correlation with the measured Surface roughness & AE Signals like signal strength, absolute energy & RMS than 50% and 60% of the dataset and better Regression co-efficient (R value) was also found at this dataset.

Fig 6 shows predicted Surface roughness values along with the measured values at pulse on time 16 µs, pulse off time 8 µs, current 5 amps and bed speed 30 µm/s at 50%, 60% & 70% training dataset. From plot it can be seen that at 70% of training set the measured and predicted values correlates better than in 50% and 60% of training set.

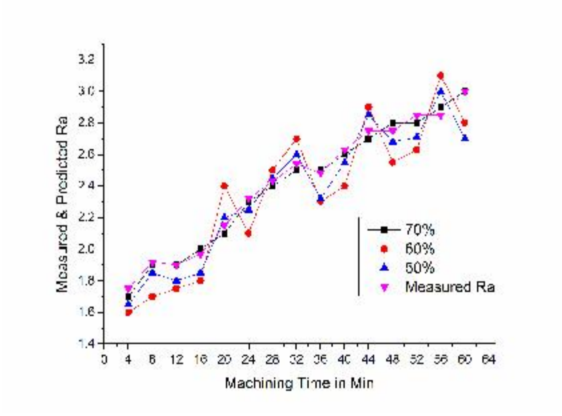

Fig 6. Measured & Predicted surface roughness for different machining time using ANN

Fig 7 shows predicted signal strength values along with the measured values at pulse on time 28 µs, pulse off time 10 µs, current 3 amps and bed speed 30 µm/s at 70% training dataset.

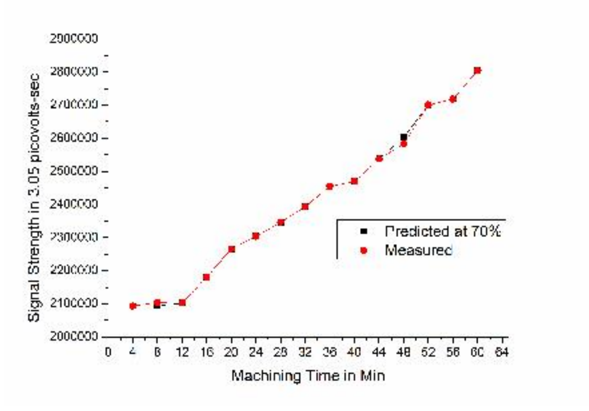

Fig 7. Measured & Predicted Signal Strength for different machining time

4. CONCLUSIONS

The present work involves machining P-20 tool steel workpiece at various process parameters. During machining, different AE signal parameters viz., Signal Strength, RMS and absolute energy from the workpiece were acquired. Surface roughness was also measured after machining. Both experimental and theoretical approaches were used to estimate roughness, signal strength, RMS and absolute energy.

Based on the experimental results, the following conclusions were drawn.

- The roughness plots have increased for higher process parameters.
- Recorded AE parameters (Absolute Energy, RMS 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 method can be considered for reliable estimation of surface roughness, and AE parameters namely signal strength, RMS and absolute energy based on the on the parameters like machining time, pulse on, pulse off, current and bed speed.
- 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.

ACKNOWLEDGEMENTS

The work reported in this paper is supported by P E S College of Engineering, through the Technical Education Quality Improvement Programme [TEQIP-II] of the MHRD, Government of India.

REFERENCES

[1] Neeraj Sharma, Rajesh Khanna and Rahuldev Gupta, "Multi Quality charaterisitics of WEDM Process Parameters RSM", *Procedia Engineering*, Vol. 64, 2013, pp. 710-719.

[2] Vinod Kumar, Kamal Jangra, Vikas Kumar, "Effect of WEDM Parameters on Machinability of Nimonic-90", Oct 19-20,2012, *Proceedings of the National Conference on Trends and Advances in Mechanical Engineering*, YMCA University of Science & Technology, Faridabad, Haryana.

[3] Cabanes I., E. Portillo, M. Marcos and J.A. Sánchez, 2008, "An industrial application for on-line detection of instability and wire breakage in wire EDM", *Journal of Materials Processing Technology*, Vol. 195, January 2008 pp.101–109.

[4] Craig Smith & Philip Koshy "Applications of acoustic mapping in electrical discharge machining" *CIRP Annals - Manufacturing Technology*, Vol. 62 2013 pp.171-174.

[5] Aniza Aliasa, Bulan Abdullaha, Norliana Mohd Abbasa, "Influence of Machine Feed Rate in WEDM of Titanium Ti-6al-4v with Constant Current (6a) Using Brass Wire", *Procedia Engineering*, Vol. 41, 2012, pp. 1806–1811.

[6] M.P. Jahan, Y.S. Wong and M. Rahman, "Evaluation of the effectiveness of low frequency workpiece vibration in deep-hole micro-EDM drilling of tungsten carbide" *Journal of Manufacturing Processes,* Vol. 14, 2012, pp. 343–359.

[7] Azlan Mohd Zain, Habibollah Haron, Sultan Noman Qasem and Safian Sharif, "Regression and ANN models for estimating minimum value of machining performance", *Applied Mathematical Modelling*, Vol. 36, 2012, pp. 1477–1492.

[8] S B Prajapati, N S Patel, V D Asal "Prediction of Process Parameters of Wire EDM for AISI A2 Using ANN*" Indian Journal of Applied Research,* Vol. 3, 2013, pp. 217-218.

[9] G Ugrasen, H V Ravindra, G V Naveen Prakash, R Keshavamurthy "Estimation of Machining Performance using MRA, GMDH and ANN in Wire EDM of EN-31" *Procedia Material Science,* Vol. 6, 2014, pp. 1788-1797.