Optimization of surface roughness values for EDM process using a hybrid method of ANFIS and GA

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ABSTRACT

Modeling of EDM process is highly attracted by the researchers and many different models and techniques are used up to now to optimize the process parameters. This study considers application of a hybrid method using genetic algorithm with ANFIS modeling of EDM parameters. ANFIS structure is built using the experimental data found in literature. D2 tool steel block is machined by a 5 axis CNC EDM in experiments. 5 parameters are selected as inputs and surface roughness values are used as output. Obtained model is used in objective function to optimize. Results show that accurate results could also be obtained by used method beneath other advantages.

Keywords *– Optimization of EDM process, ANFIS, GA*

I. INTRODUCTION

Nontraditional machining processes have taken place of conventional machining processes in industry by the time as they offered high capacity and accuracy especially in production of complex shapes. Wire EDM is one of the oldest and mostly known nontraditional processes. It has a wider application area but it is well suited to production of dies so that it is often possible to produce punch and die in a single cut.

Most important parameter in production of die is its dimensional accuracy. So many researchers have focused on investigation of parameters effect on dimensional accuracy and finding out the optimum parameters acquiring best accuracy.

This study concerns finding out optimum surface roughness values for certain parameters. Following section will give brief explanation on Wire EDM process and its parameters. Later, studies on literature will be summarized. Experimental data and method used will be given at next section. Lastly, obtained results will be displayed and article will be concluded with comments on them.

II. WIRE EDM PROCESS

EDM process remove chips from the workpiece by the help of heat and impact loads which occurs during spark formation and consequently sudden expansion of dielectric fluid. Wire EDM differs from EDM process in using continuously moving wire instead of a pre-shaped tool. Fig. 1 shows the schematic view of the process. Power supply generates potential difference (voltage) between the workpiece and the wire. When the distance between workpiece and wire becomes close enough to produce spark, dielectric fluid and material are heated quickly. Also, spark causes fluid rapid expansion and impact load occurs on workpiece. So, a small amount of chips are removed from the surface close to the wire. As the wire goes on a path, it cuts the workpiece.

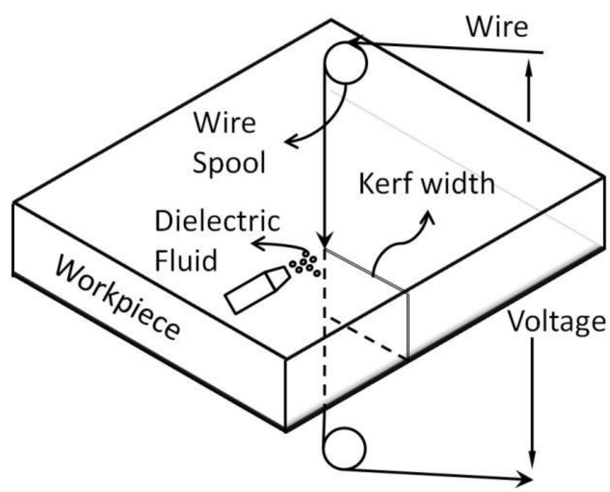

Figure1. Some process parameters

Important process parameters are related to power supply (discharge current, pulse on time, pulse off time and pulse frequency), wire (diameter, kerf width, material, tension, feed rate and control unit), workpiece (material, shape and dimensions) and dielectric fluid (flow rate, material and flushing method). Mostly investigated process responses are material removal rate (MRR), surface roughness value (SRV) and wear wire ratio (WWR). In this study, only surface roughness value is concerned even though MRR values are found in experiments.

III. STUDIES IN LITERATURE

There are numerous studies in literature. Here only some of them similar to our study will be given. For more information, review studies could be checked [1-3].

Liao et al [4] worked on SKD11 alloy steel workpiece. They used TAGUCHI quality design concept to generate L18 mixed orthogonal array for the experiments. They selected table feed, pulse-on time, pulse-off time, wire speed, wire tension and flushing as the parameters. MRR and SRV have been selected as performance parameters. They made an ANOVA analysis. Ramakrishnan and Karunamoorthy [5] used heat treated tool steel as the work material for experimentation. L16 orthogonal array was generated. Pulse on time, Wire tension, Delay time, Wire feed speed and Ignition current intensity were selected as parameters. MRR, SRV and WRR were considered together using weighting factors. They made an ANOVA analysis. Tosun et al [6] used SAE 4140 steel as the workpiece material. Pulse duration, open circuit voltage, wire speed and dielectric fluid pressure are the parameters affecting the SRV. Full factorial experimental sets are used in ANOVA analysis. Kanlayasiri and Boonmung [7] used DC53 cold die steel in full factorial experimental sets. Pulse-on time, pulse-off time, pulse-peak current, and wire tension are the process parameters and they used ANOVA analysis for SRV. Bobbili et al [8] used medium carbon UHS steel in L27 orthogonal array experimental sets. Pulse-on time, pulse-off time, wire feed, flushing pressure, spark voltage, and wire tension are the process parameters. They used ANOVA analysis for each of MRR and SRV. Kuruvilla and Ravindra [9] used hot die steel in L16 orthogonal array experimental setups. Pulse-on duration, current, pulse-off duration, bed-speed and flushing rate are the process parameters. They used ANOVA analysis for each of MRR, SRV and dimensional error and also regression model is obtained and used with GA.

Besides ANOVA analysis, there are several different methods used in literature: Response Surface Methodology [10-12], Grey Relational Analysis [13-15] etc.

This study used discharge current, pulse duration, pulse frequency, wire speed, wire tension and dielectric flow rate as process parameters and optimum surface roughness value is obtained using ANFIS and GA together.

IV. EXPERIMENTS AND METHOD

The experimental data set in this paper come from Datta and Mahapatra [15]. They performed the experiments on ROBOFIL 100 high precision 5 axis CNC WEDM (Charmilles Technologies Corporation). They used stratified diameter 0.25 mm zinc coated copper wire to machine 10 mm thick 25 mm high rectangular workpiece. They have measured MRR, SRV and kerf width values but in this study only SRV is considered. Data on experimental setup and measured values are given in Table 1 and 2.

Table 1. L27 Experimental Sets

Exp.	P1	P2	P3	P4	P5	P6
1	1	1	1	1	1	1
2	1	1	1	1	2	2
3	1	1	1	1	3	3
4	1	2	2	2	1	1
5	1	2	2	2	2	2
6	1	2	2	2	3	3
7	1	3	3	3	1	1
8	1	3	3	3	2	2
9	1	3	3	3	3	3
10	2	1	2	3	1	2
11	2	1	2	3	2	3
12	2	1	2	3	3	1
13	2	2	3	1	1	2
14	2	2	3	1	2	3
15	2	2	3	1	3	1
16	2	3	1	2	1	2
17	2	3	1	2	2	3
18	2	3	1	2	3	1
19	3	1	3	2	1	3
20	3	1	3	2	2	1
21	3	1	3	2	3	2
22	3	2	1	3	1	3
23	3	2	1	3	2	1
24	3	2	1	3	3	2
25	3	3	2	1	1	3
26	3	3	2	1	2	1
27	3	3	2	1	3	2

Table 2. Process Parameter Values

Parameter	Range (1-2-3)	
Discharge Current (amp)	16-24-32	P1
Pulse Duration (μsec)	3.2-6.4-12.8	P2
Pulse Frequency (KHz)	40-50-60	P3
Wire Speed (m/min)	7.6-8.6-9.2	P4
Wire Tension (g)	1000-1100-1200	P5
Dielectric Flow Rate (bars)	1.2-1.3-1.4	P6

Table 3. Surface Roughness Values (µm)

Exp.	SRV	Exp.	SRV	Exp.	SRV
1	3,7195	10	3,773	19	3,6897
2	3,6107	11	3,6642	20	3,8641
3	3,5019	12	3,8386	21	3,7553
4	4,1017	13	4,0184	22	4,1301
5	3,9929	14	3,9096	23	4,3045
6	3,8841	15	4,084	24	4,1957
7	4,4839	16	4,4588	25	4,3755
8	4,3751	17	4,35	26	4,5499
9	4,2663	18	4,5244	27	4,4411

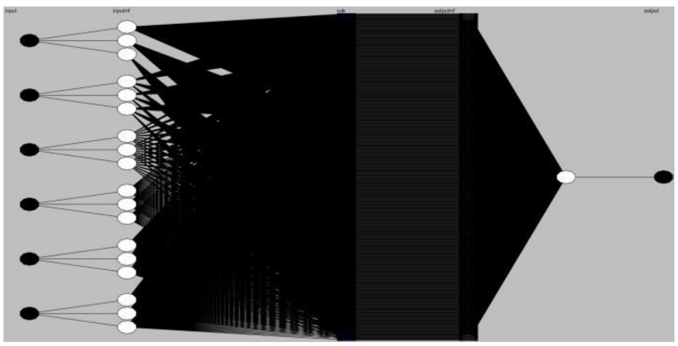

Figure 2. ANFIS structure

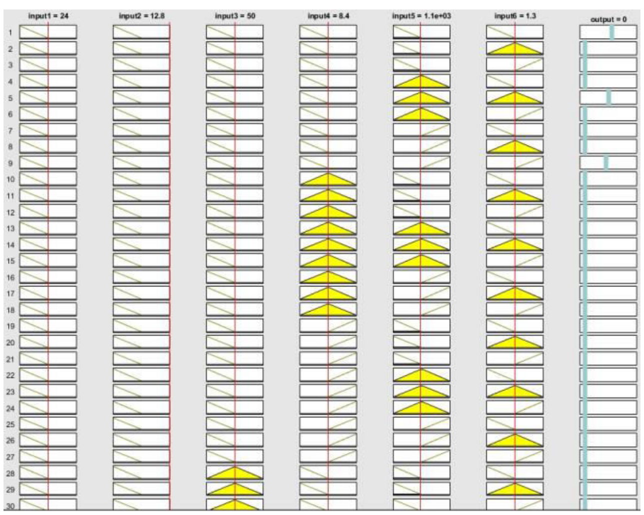

Figure 3. Rule structure

Using the experimental data given above, an ANFIS structure is built to model the process by the help of MATLAB software. Sugeno type fuzzy inference is selected and triangular-shape membership function having 3 parameters is preferred to simplify the model. As a result, 729 rules are generated. Fig. 2 and 3 show the built structure and the rules, respectively. Training session is completed in two iterations. Predicted values are highly correlated with experimental data, having max 0.001 error value, as seen in Fig. 4.

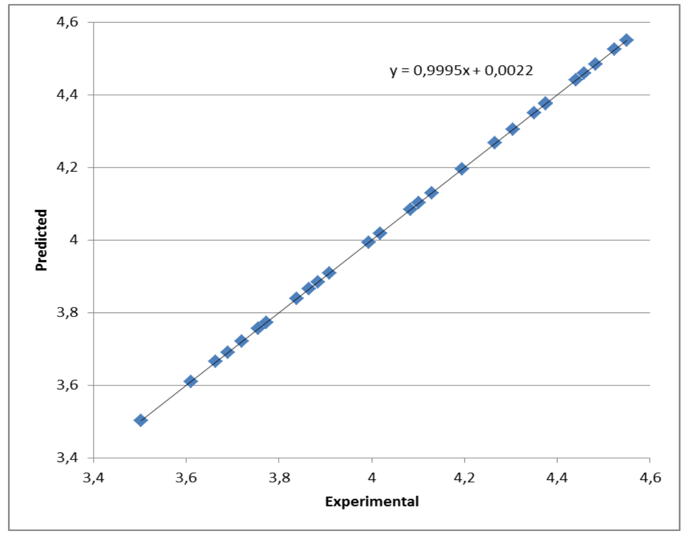

Figure 4. Comparison between experimental and predicted data.

Later, genetic algorithm module with default settings is used to find optimum parameters in the range given in Table 1. Obtained results and comparison with literature are given in Table 4.

V. RESULTS

Following table shows the optimum parameter values found in this study, given in original and another study from literature using same data.

Table 4. Surface Roughness and Related Parameter Values

Ref.	P1	P2	P3	P4	P5	P6	SRV
[15]	16	3.2	40	7.6	1200	1.4	3.502
Our	31.529	5.194	46.392	7.601	1130.762	1.277	≈0

Datta and Mahapatra [15] have used two different methods: Response Surface Methodology and Grey Relational Analysis Method. Both method has given the same result (third experiment which is also the one having the least surface roughness value among the experimental data). On the other hand, our methodology has given a result very close to zero. Mathematical models can indicate optimum values with extreme values. Even though the values seem not realistic, optimum point is expected to be there.

VI. CONCLUSION

In this study, it is expected to use ANFIS structure to model experimental data and to use obtained model in optimization stage with GA. Results showed that it is appropriate to use ANFIS+GA hybrid method as the model covers whole parameter range and results become much more accurate when compared with ANOVA analysis.

Also, model building becomes much easier by ANFIS as you have already obtained the relation between parameters as a result of the experiments. So, it is believed that optimum parameter values can be found in a short time by used method if there is enough quantity of experiments.

REFERENCES

[1] N.M. Abbas, D.G. Solomon and M.F. Bahari, A review on current research trends in electrical discharge machining (EDM), *International Journal of Machine Tools and Manufacture, 47(7-8)*, 2007, 1214-1228.

[2] A.S. Shivade and V.D. Shinde, A review on advanced multi-optimization methods for WEDM, *International Journal of Scientific Research Engineering & Technology, 2(7)*, 2013, 435-439.

[3] T. Muthuramalingam and B. Mohan, A review on influence of electrical process parameters in EDM process, *Archives of Civil and Mechanical Engineering, 15(1)*, 2015, 87-94.

[4] Y.S. Liao, J.T. Huang, and H.C. Su, A study on the machining-parameters optimization of wire electrical discharge machining, *Journal of Materials Processing Technology, 71(3)*, 1997, 487-493.

[5] J.T. Huang and Y.S. Liao, Optimization of machining parameters of wire-EDM based on grey relational and statistical analyses, *International Journal of Production Research, 41(8)*, 2003, 1707-1720.

[6] N. Tosun, C. Cogun, and A. Inan, The effect of cutting parameters on workpiece surface roughness in wire EDM, *Machining Science and Technology, 7(2)*, 2003, 209-219.

[7] K. Kanlayasiri and S. Boonmung, An investigation on effects of wire-EDM machining parameters on surface roughness of newly developed DC53 die steel, *Journal of Materials Processing Technology, 187*, 2007, 26-29.

[8] R. Bobbili, V. Madhu and A.K. Gogia, Effect of wire-EDM machining parameters on surface roughness and material removal rate of high strength armor steel, *Materials and Manufacturing Processes, 28(4)*, 2013, 364-368.

[9] N. Kuruvila and H.V. Ravindra, Parametric influence and optimization of wire EDM of hot die steel, *Machining Science and Technology, 15(1)*, 2011, 47-75.

[10] A.B. Puri and B. Bhattacharyya, Modeling and analysis of white layer depth in a wire-cut EDM process through response surface methodology, *The International Journal of Advanced Manufacturing Technology, 25(3-4)*, 2005, 301-307.

[11] M.S. Hewidy, T.A. El-Taweel and M.F. El-Safty, Modelling the machining parameters of wire electrical discharge machining of Inconel 601 using RSM, *Journal of Materials Processing Technology, 169(2)*, 2005, 328-336.

[12] C.J. Tzeng, Y.K. Yang, M.H. Hsieh and M.C. Jeng, Optimization of wire electrical discharge machining of pure tungsten using neural network and response surface methodology, *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 225(6)*, 2011, 841-852.

[13] G. Rajyalakshmi and P.V. Ramaiah, Multiple process parameter optimization of wire electrical discharge machining on Inconel 825 using Taguchi grey relational analysis, *The International Journal of Advanced Manufacturing Technology, 69(5-8)*, 2013, 1249-1262.

[14] J.H. Jung and W.T. Kwon, Optimization of EDM process for multiple performance characteristics using Taguchi method and Grey relational analysis, *Journal of Mechanical Science and Technology, 24(5)*, 2010, 1083-1090.

[15] S. Datta and S. Mahapatra, Modeling, simulation and parametric optimization of wire EDM process using response surface methodology coupled with grey-Taguchi technique, *International Journal of Engineering, Science and Technology, 2(5)*, 2010, 162-183.