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Process Parameters Optimization of Wire Cut Electric Discharge Machining Using Artificial Neural Network

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ABSTRACT: This article describes an artificial neural network (ANN) model that can simultaneously predict kerf width and surface roughness to obtain precise results. In order to understand the effect of ANN on the estimated value of Kerf width and surface roughness. This study refers to actual machining experiment. The Matlab software is used for simulation. The input layer with 4 nodes, and the output layer with 2 nodes, we have designed eight networks with different numbers of hidden layer and nodes which are 4-2-2, 4-4-2, 4-8-2, 4-9-2, 4-2-2-2, 4-4-4-2, 4-8-8-2 and 4-9-9-2 structures. We found that the 4–4-4–2 structure for the 0.25 mm brass wire provides the best ANN model for predicting the kerf width and surface roughness values. This study shows that the kerf width and surface roughness of the WEDM can be enhanced by changing the number of hidden layers and the number of nodes in the ANN network, especially for predicting the value of the cutting surface roughness and kerf width. As a result of the prediction, it recommends the combination of cutting parameters to obtain best surface finish with very close tolerance due to minimum kerf width.

Key Words: Optimization, Voltage gap, Kerf width, Artificial Neural Network, Feedforward backpropagation, Algorithm, etc.

1. INTRODUCTION:

As the requirements for high surface quality and complex geometry processing continue to increase, traditional processing methods are being replaced by non-traditional processing methods. The WEDM is a non-conventional machining process based on Electric Discharge Machining. It is a non-contact electro-thermal machining process in which, the heat energy generated by spark is used to remove material from the workpiece. The spark is developed between workpiece & tool by electrical discharge. The high frequency discharge causes the material to melt and evaporate on the surfaces of the two electrodes. In order to improve the material removal rate, the wire cutting process works in a non-conductive liquid, that is, a dielectric liquid. Therefore, only conductive and semi-conducting materials can be machined with WEDM. WEDM can be used to machine complex profiles in macro to micro dimensions.[1]

Surface roughness and kerf width are important factors of the machining process. The objective of optimization is to achieve the minimum kerf width and the good surface finish simultaneously. This article proposes a method to determine the best combination of control parameters in the wire processing process Wire Electric Discharge Machining process.

2. EXPERIMENTAL ENVIRONMENT:

- Dielectric fluid: The gap between workpiece and electrode was filled with a circulating Commercial grade EDM oil.
- Tool Wire: Brass of 0.25 mm diameter with uniform circular cross-section.
- Workpiece material: Steel S316.

3. EXPERIMENTAL DATA

Number of trials	Gap Voltage	Pulse on Time	Pulse off Time	Wire Feed	Surface Roughness	Kerf Width
1	45	2	6	4	2.48	0.308
2	40	8	8	10	2.2	0.294
3	55	4	4	6	2.31	0.296
4	50	6	10	8	2.38	0.303
5	40	6	6	8	2.31	0.309
6	50	4	8	6	2.86	0.296
7	45	8	4	10	2.35	0.297

8	55	2	10	4	2.03	0.3
9	40	4	6	6	2.53	0.313
10	45	8	10	10	2.19	0.299
11	40	6	8	8	2.38	0.311
12	55	8	6	6	2.3	0.303
13	50	4	4	10	2.04	0.298
14	40	2	8	6	2.1	0.294
15	55	6	6	8	2.45	0.297
16	45	4	10	4	2.32	0.303
17	40	8	8	10	2.8	0.309
18	55	4	4	6	2.23	0.311
19	40	8	6	8	2.37	0.291
20	45	2	8	4	2.34	0.312
21	45	2	6	4	2.49	0.308
22	40	8	8	10	2.23	0.292
23	55	4	4	6	2.33	0.296
24	50	6	10	8	2.37	0.303
25	40	6	6	8	2.34	0.309
26	50	4	8	6	2.87	0.292
27	45	8	4	10	2.34	0.297
28	55	2	10	4	2.02	0.3
29	40	4	6	6	2.51	0.313
30	45	8	10	10	2.17	0.291
31	40	6	8	8	2.39	0.311
32	55	8	6	6	2.29	0.303
33	50	4	4	10	2.05	0.298
34	40	2	8	6	2.01	0.294
35	55	6	6	8	2.35	0.292
36	45	4	10	4	2.38	0.303
37	40	8	8	10	2.78	0.309
38	55	4	4	6	2.23	0.311
39	40	8	6	8	2.37	0.29
40	45	2	8	4	2.35	0.312
41	45	2	6	4	2.48	0.308
42	40	8	8	10	2.1	0.299
43	40	2	4	10	2.75	0.299
44	45	2	6	8	2.83	0.297
45	50	4	8	6	2.07	0.301
46	55	4	10	4	2.25	0.311
47	40	6	8	6	2.02	0.292
48	50	6	10	4	2.33	0.314
49	45	8	4	10	2.41	0.302
50	55	8	10	8	2.79	0.296

4. DEVELOPMENT OF THE ANN PREDICTION MODEL

Based on the ANN toolbox of Matlab software, following affecting factors:
(i) Network algorithm.
(ii) Transfer function.
(iii) Training function.
(iv) Learning function.
(v) Performance function

Four different parameters are additionally viewed as that can impact the viability of the model and these are:
(i) Network structure.

(ii) Number of training data.
(iii) Number of testing data.
(iv) Normalization of data input

4.1 Network structure:

The ANN network structure consists of layers and nodes, which are also called as Neurons. A figure of an ANN network with layers and nodes, this is called as an Implicit Model. Our ANN network structure consists of 4 layers which are the input layer, hidden layer and 2 output layers. An ANN structure with no hidden layers can be possible. The network structure has 4 nodes in the input layer, *x* nodes in the first hidden layer, *y* nodes in the second hidden layer, *z* nodes in the n^{th} hidden layer and one node in the output layer. Four nodes for the input layer stand for the four decision values of the case study which are gap Voltage(V_g) , Pulse on time (P_{on}) , Pulse off time (P_{off}), Wire feed (f_w).

Two nodes for the output layer stands for the predicted kerf width, surface roughness value. When considering that a multilayer feedforward network is applied at the n^{th} hidden layer with *x*, *y*, *z* the example network given in Fig.1 could be defined as a 4–*x*-*y*-*z*–2 structure.

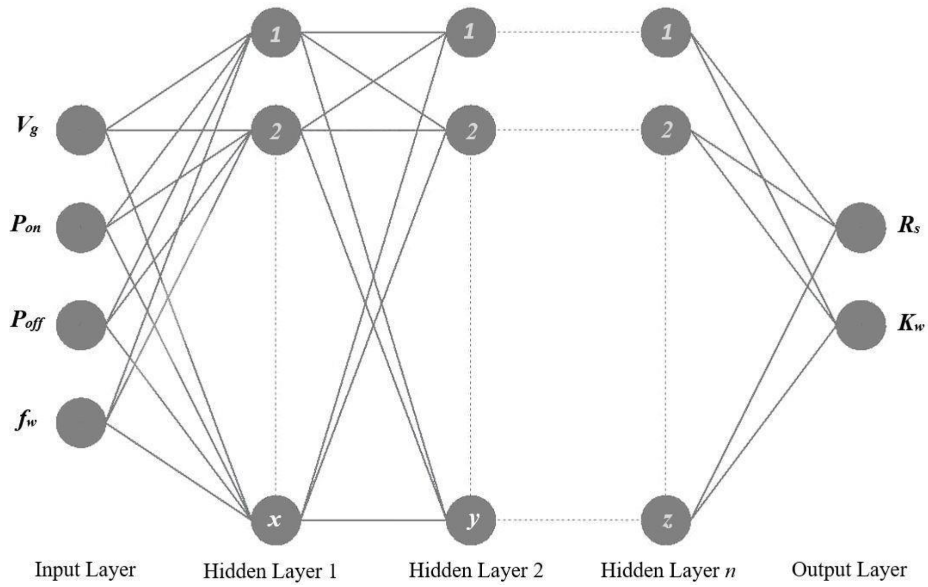
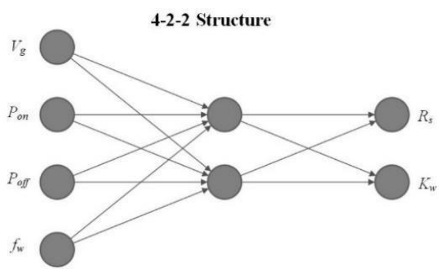
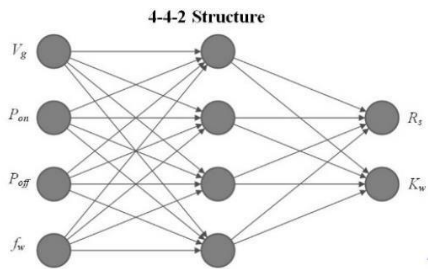


Figure 1. Basic Structure

The ANN model is developed by trial-and-error method to obtain the best result. This process is performed by adjusting the number of layers and the number of nodes of hidden layer(s) of the network structure. Performers are free to examine any number of hidden layers with any number of nodes for each hidden layer. Although the number of hidden layers and nodes in each area of the hidden layer depends on the complexity of the mapping, computer memory, calculation time and the required data management effect. So many layer & nodes lead to consume more computer memory & processing time. Hence possible solution for this problem is to adjust the hidden structure of the ANN network. This study prefers to use different network structures and compare the results by following the recommended number of nodes for the hidden layer : "n/2", "1n", "2n", and"2n + 1" where n is the number of input nodes. [2]
Since the number of variables in our study are gap voltage (v) , Pulse on time (P_1) , Pulse off time (P_2), Wire feed (f). the recommended number of nodes in the hidden layer: 4/2=2, 1×4=4, 2×4=8, (2×4)+1=9. According to this study applies eight network structures, which are 4-2-2, 4-4-2, 4-8-2, 4-9-2, 4-2-2-2, 4-4-4-2, 4-8-8-2, 4-9-9-2.





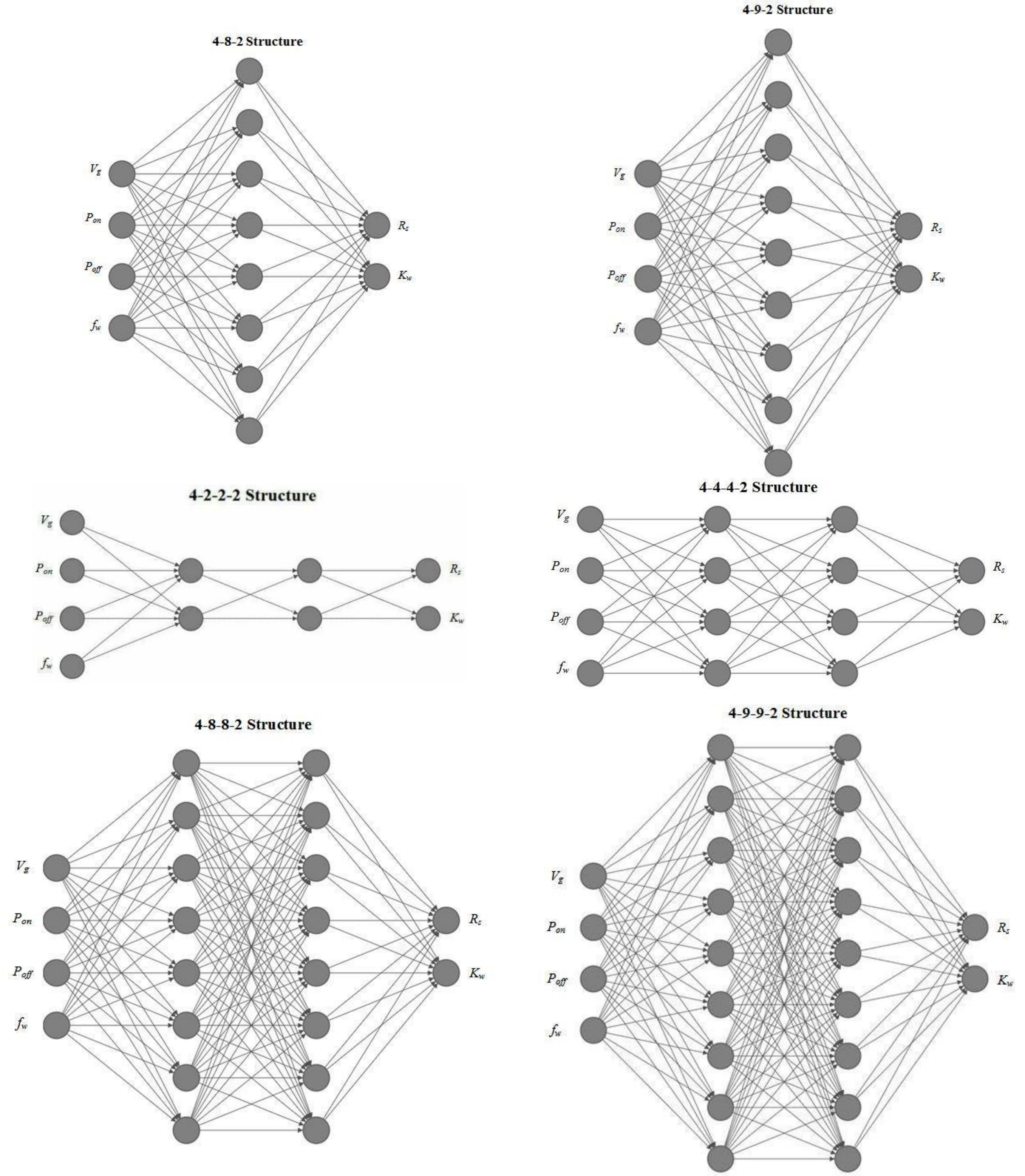


Figure 2. Network structure models

4.2 Quantity of training and testing data

In ANN, an increment in amount of training data will increase chances of getting more accurate model. Hence, we took 50 sample data. By applying ANN model this study is expected to give an accurate predictive result for surface finish & kerf width.

4.3 Proportion of training and testing data

It is important to avail enough training as well as testing data. As we are having 50 input sample data it is not a big issue to separate both training and testing data and there is no general guidelines which could be followed to measure the ratio between them. [2]
Where recommended ratio of training and testing sample is taken as 90%-10%,85%-15% and 80%-20%. To fit in with the available experimental sample size of 50, the preferred ratio is selected as 85%:15%. So, the recommended amount of training and testing samples are:
1. (85/100) × 50 = 42-43 training samples,
2. (15/100) × 50 = 07-08 data testing samples.

4.4 Normalization of data input/output

Data normalization is usually done before training and testing. We can normalize the quantitative variable to some standard range such as 0 to 1 or -1 to 1. When using nonlinear transfer functions such as logistic sigmoid function at the output node, the expected output value must be converted into the actual output range of the network. Output and input to avoid calculation problems. Two potential normalization equations are used to normalize the original input and output data.

$$x_i = \frac{2}{d_{max}-d_{min}}(d_i - d_{min}) - 1 \quad ....[3]$$

$$x_i = \frac{0.8}{d_{max}-d_{min}}(d_i - d_{min}) + 0.1 \quad ....[4]$$

Where,
d_{max} = The maximum value of the input/output data,
d_{min} = The minimum value of the input/output data,
d_i = The i^{th} input/output data.
Second equation is considered for this study.

4.5 Network algorithm

There are different ANN network algorithms for the modelling purpose such as Cascade-forward BP, Elman BP, Perceptron, Radial Basis, Self-Organizing Map and Time-delay BP. Feedforward backpropagation (BP) algorithm is mainly used by researchers. [5]
A feedforward network based on backpropagation is a multilayered model consisting of one or more hidden layers located between the input and output layers. Each layer is composed of elements that receive input from the elements directly below and send their output to the layer unit directly above the unit.

5. PERFORMANCE OF FESIBLE STRUCTURE

The performance of above structures (4-2-2, 4-4-2, 4-8-2, 4-9-2, 4-2-2-2, 4-4-4-2, 4-8-8-2, 4-9-9-2) are as follows:

For 4-2-2 Structure

Roughness		
Actual	Predicted	Error
2.75	2.01	0.7400
2.83	2.01	0.8200
2.07	2.01	0.0600
2.25	2.037004	0.2130
2.25	2.01	0.2400
2.33	2.732363	0.4024
2.41	2.01	0.4000
2.79	2.01	0.7800
Average Error =		0.4569

Kerf width		
Actual	Predicted	Error
0.299	0.291925	0.007075
0.297	0.28655	0.01045
0.301	0.294169	0.006831
0.311	0.306276	0.004724
0.292	0.317565	0.025565
0.314	0.313184	0.000816
0.302	0.297177	0.004823
0.296	0.31124	0.01524
Average Error =		0.0094

Total error for structure 4-2-2 is (0.4569+0.0094)/2 = 0.23315

For 4-4-2 Structure

Roughness		
Actual	Predicted	Error
2.75	2.349845	0.4002
2.83	2.349845	0.4802
2.07	2.349845	0.2798
2.25	2.349845	0.0998
2.25	2.349845	0.0998
2.33	2.349845	0.0198
2.41	2.01	0.4000

Kerf width		
Actual	Predicted	Error
0.299	0.320947	0.021947
0.297	0.320947	0.023947
0.301	0.320947	0.019947
0.311	0.320947	0.009947
0.292	0.320947	0.028947
0.314	0.320947	0.006947
0.302	0.321	0.019

2.79	2.01	0.7800	0.296	0.321	0.025
Average Error =		0.3200	Average Error =		0.0195

Total error for structure 4-4-2 is (0.3200+0.0195)/2 = 0.16975

For 4-8-2 Structure

Roughness			Kerf width		
Actual	Predicted	Error	Actual	Predicted	Error
2.75	2.081409	0.6686	0.299	0.296578	0.002422
2.83	2.188141	0.6419	0.297	0.307893	0.010893
2.07	2.865497	0.7955	0.301	0.298316	0.002684
2.25	2.153067	0.0969	0.311	0.304682	0.006318
2.25	2.864617	0.6146	0.292	0.297854	0.005854
2.33	2.868195	0.5382	0.314	0.300747	0.013253
2.41	2.86999	0.4600	0.302	0.301627	0.000373
2.79	2.869993	0.0800	0.296	0.300566	0.004566
Average Error =		0.4870	Average Error =		0.0058

Total error for structure 4-8-2 is (0.4870+0.0058)/2 = 0.2464

For 4-9-2 Structure

Roughness			Kerf Width		
Actual	Predicted	Error	Actual	Predicted	Error
2.75	2.126318	0.623682	0.299	0.320915	0.021915
2.83	2.194286	0.635714	0.297	0.320897	0.023897
2.07	2.848259	0.778259	0.301	0.303688	0.002688
2.25	2.076434	0.173566	0.311	0.31967	0.00867
2.25	2.288805	0.038805	0.292	0.310638	0.018638
2.33	2.067892	0.262108	0.314	0.320601	0.006601
2.41	2.350511	0.059489	0.302	0.320856	0.018856
2.79	2.290943	0.499057	0.296	0.310579	0.014579
Average Error =		0.383835	Average Error =		0.014481

Total error for structure 4-9-2 is (0.383835+0.014481)/2 = 0.199159

For 4-2-2-2 Structure

Roughness			Kerf Width		
Actual	Predicted	Error	Actual	Predicted	Error
2.75	2.818202	0.0682	0.299	0.312909	0.013909
2.83	2.827047	0.0030	0.297	0.312243	0.015243
2.07	2.058776	0.0112	0.301	0.299085	0.001915
2.25	2.19051	0.0595	0.311	0.30161	0.00939
2.25	2.384459	0.1345	0.292	0.297422	0.005422
2.33	2.471581	0.1416	0.314	0.300429	0.013571
2.41	2.350018	0.0600	0.302	0.300748	0.001252
2.79	2.490278	0.2997	0.296	0.301614	0.005614
Average Error =		0.0972	Average Error =		0.0083

Total error for structure 4-2-2-2 is (0.0972+0.0083)/2 = 0.05275

For 4-4-4-2 Structure

Roughness			Kerf Width		
Actual	Predicted	Error	Actual	Predicted	Error
2.75	2.759505	0.0095	0.299	0.299516	0.000516
2.83	2.793119	0.0369	0.297	0.302145	0.005145

2.07	2.098304	0.0283		0.301	0.317039	0.016039
2.25	2.221698	0.0283		0.311	0.300102	0.010898
2.25	2.171926	0.0781		0.292	0.293416	0.001416
2.33	2.227266	0.1027		0.314	0.287627	0.026373
2.41	2.399856	0.0101		0.302	0.303542	0.001542
2.79	2.556548	0.2335		0.296	0.3	0.004
Average Error =		0.0659		Average Error =		0.0082

Total error for structure 4-4-4-2 is (0.0659+0.0082)/2 = 0.03705

For 4-8-8-2 Structure

Roughness			Kerf Width		
Actual	Predicted	Error	Actual	Predicted	Error
2.75	2.406461	0.3435	0.299	0.307887	0.008887
2.83	2.325536	0.5045	0.297	0.298097	0.001097
2.07	2.340034	0.2700	0.301	0.301743	0.000743
2.25	2.306899	0.0569	0.311	0.296071	0.014929
2.25	2.364439	0.1144	0.292	0.303356	0.011356
2.33	2.344918	0.0149	0.314	0.300984	0.013016
2.41	2.320768	0.0892	0.302	0.298803	0.003197
2.79	2.346641	0.4434	0.296	0.300932	0.004932
Average Error =		0.2296	Average Error =		0.0073

Total error for structure 4-8-8-2 is (0.2296+0.0073)/2 = 0.11845

For 4-9-9-2 Structure

Roughness			Kerf Width		
Actual	Predicted	Error	Actual	Predicted	Error
2.75	2.01	0.7400	0.299	0.309036	0.010036229
2.83	2.01	0.8200	0.297	0.303611	0.006610606
2.07	2.01	0.0600	0.301	0.301045	0.000045
2.25	2.01	0.2400	0.311	0.292936	0.018063977
2.25	2.010016	0.2400	0.292	0.306674	0.014674171
2.33	2.01	0.3200	0.314	0.292302	0.021697765
2.41	2.348283	0.0617	0.302	0.299696	0.002304327
2.79	2.01	0.7800	0.296	0.299279	0.003278872
Average Error =		0.4077	Average Error =		0.0096

Total error for structure 4-9-9-2 is (0.4077+0.0096)/2 = 0.2086

6. DETERMINATION OF THE BEST ANN MODEL

The above developed ANN model used to determine the surface finish and kerf width for all possible combinations. Finally, the results of this study proposed best of these combinations. We can easily differentiate most accurate one. We can use most accurate model for the future use or for research purposes. By comparing the errors of different structures, we can easily differentiate that the structure 4-4-4-2 has lowest error (0.0659) in surface roughness among all. Structure 4-8-2 has least error in kerf width. But when we compare both the models, structure 4-4-4-2 is more reliable as compared to 4-8-2. We can determine the performance of models from their graphs as well. following figure shows the graphs of 4-4-4-2 structure.

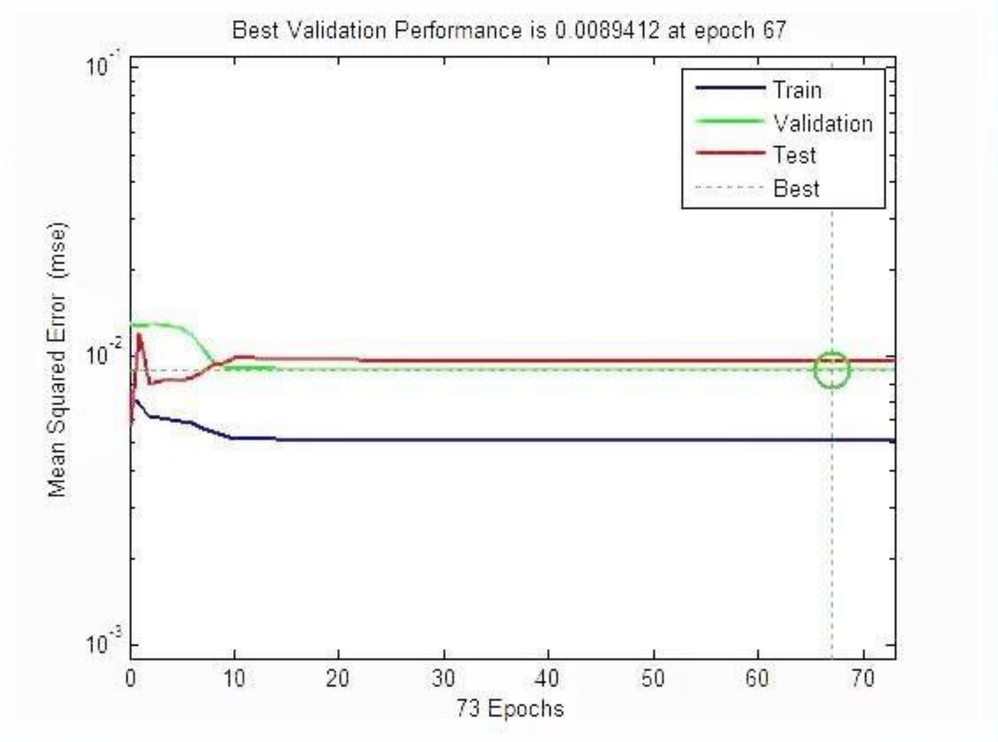


Figure 3. Plotperform

We can measure network performance by comparing the root mean square error (MSE) of the predicted output with actual experimental data. The goal is to make the MSE as close to zero as possible, Between the networks output and the experimental data value. Repeated the training network until there are no further improvements to the MSE. The structure 4-4-4-2 stopped at 73 iterations.

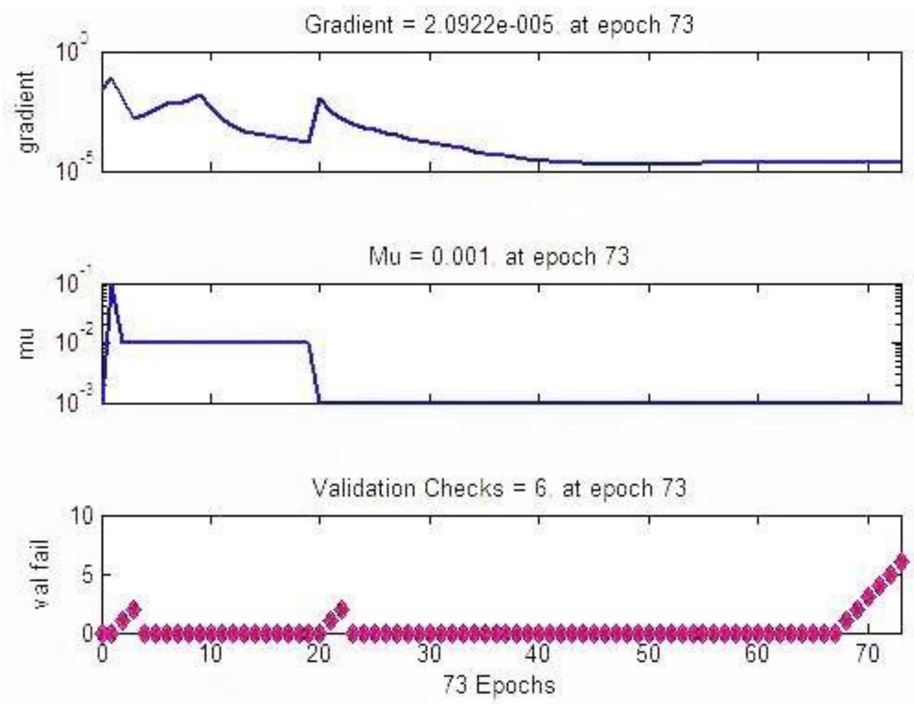


Figure 4 Plottrainstate

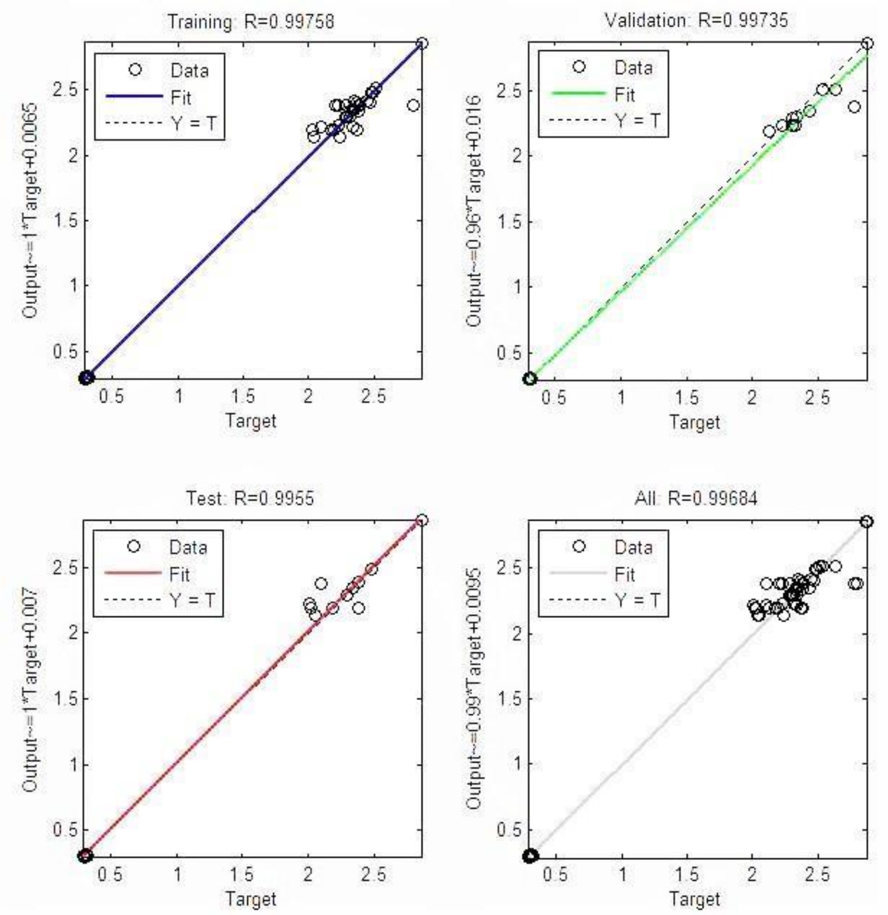


Figure 5. plotregression

7. CONCLUSION

In our study of ANN, we took different approach to develop prediction model with 2 output factors that are kerf width and surface roughness, we found that calculating 2 output parameters at a time will save the time (as well as resources) without compromising its accuracy. The structure 4-4-4-2 gave the best result with minimum error of 0.03705.

This modeling was executed by applying different layered feed forward back propagation neural network. Derived model was verified using statistical indicator as MSE was shown justifiable to map nonlinear inputs/output relationships which is as per the ANN model.

REFERENCES

1. J. Kapoor, S. Singh, J.S. Khamba, [2010]: “Recent Developments in Wire Electrodes for High Performance WEDM”, Proceedings of the World Congress on Engineering 2010, Vol II ,WCE 2010, June 30 - July 2, 2010, London, U.K.

2. Guoqiang Zhang, B. Eddy Patuwo, Michael Y. Hu [1998], Forecasting with artificial neural networks:: The state of the art, International Journal of Forecasting, Volume 14, Issue 1, Pages 35-62, ISSN 0169-2070, (https://www.sciencedirect.com/science/article/pii/S0169207097000447)

3. Ezugwu, E. O., Fadare, D. A., Bonneya, J., Silva, R. B. D., & Sales, W. F. [2005]. Modelling the correlation between cutting and process parameters in highspeed machining of Inconel 718 alloy using an artificial neural network. International Journal of Machine Tools and Manufacture, 45, 1375–1385.

4. Sanjay, C., & Jyothi, C. (2006). A study of surface roughness in drilling using mathematical analysis and neural networks. International Journal of Advanced Manufacturing Technology, 29, 846–852.

5. Zuperl, U. & Cus, Franci, [2003], Optimization of cutting conditions during cutting by using neural networks, Robotics and Computer-Integrated Manufacturing, 19, 189-199, 10,1016/S0736-5845(02)00079-0.

6. M.P. Jahan, M. Rahman, Y.S. Wong, [2011]: "A review on the conventional and microelectro discharge machining of tungsten carbide"; International Journal of Machine Tools & Manufacture, ISSN 0890-6955, Volume 51, Pages 837–858. https://www.sciencedirect.com/science/article/pii/S0890695511001660.

7. R.E. Williams, K.P. Rajurkar, [1991]: "Study of Wire Electrical Discharge Machining Surface Characteristics", Journal of Materials Processing Technology, Vol. 28, pp.486-493. https://www.sciencedirect.com/science/article/pii/092401369190212W

8. G. Indurkhya, K.P. Rajurkar, [1992]: "Artificial Neural Network Approach in Modeling of EDM Process", Proceedings of Artificial Neural Networks in Engineering (ANNIE' 92) Conference, St.Louis, Missouri, U.S.A., 15-18 November, pp. 845-890.

9. D. Scott, S. Boyina, K.P. Rajurkar, [1991]: "Analysis and Optimization of Parameter Combination in Wire Electrical Discharge Machining", International Journal of Production Research, Vol. 29, No. 11, pp. 2189-2207.

10. Y.S. Tarng, S.C. Ma, L.K. Chung, [1995]: "Determination of Optimal Cutting Parameters in Wire Electrical Discharge Machining", International Journal of Machine Tools and Manufacture, Vol. 35, No. 129, pp.1693-1701.

11. A. Klinka, Y.B. Guoa, F. Klockea [2011]: "Surface integrity evolution of powder metallurgical tool steel by main cut and finishing trim cuts in wire-EDM", 1st CIRP Conference on Surface Integrity (CSI) Procedia Engineering 19, pp 178 – 183.

12. K.E.Trezise, [1982]: "A Physicist's View of Wire EDM", Proceedings of the International Conference on Machine Tool Design and Research, Vol. 23, pp 413-419.

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