J. Inst. Eng. India Ser. D
https://doi.org/10.1007/s40033-024-00693-w

ORIGINAL CONTRIBUTION

Optimization Process to Develop Tungsten Carbide Reinforced with Aluminium MMCs Using Surface Plots and ANN

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Received: 2 February 2024 / Accepted: 6 March 2024

Abstract Material selected for this study is A356 and four percentage of tungsten carbide (WC) powder for the fabrication of metal matrix composites. In this paper, a methodology is identified to find the co-relating higher order and the interactive influences of different input parameters affecting performance characteristics such as MRR, tool wear rate and surface roughness in wire electric discharge machining process using surface plots and artificial neural network. Voltage, flushing pressure, pulse on time and discharge current are the process parameters needed to be optimized to achieve optimum material removal rate, surface roughness and tool wear rate. Finding the ideal set of process parameters is achieved using artificial neural network which is a supervised machine learning algorithm and results are compared with RSM method. Results show that supervised machine learning technique (ANN) is performing better than the Response surface methodology (RSM) in terms of performance predictions.

Keywords A356 · WC · Machine learning · Wire EDM · Optimization

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Introduction

Now a day, one of the major problems faced by the manufacturing industries is optimum selection of machining parameters to enhance the performance parameters like material removal rate and surface roughness. In conventional method, process parameters are selected based on trial and error method and by experienced operators. Wire EDM is the one of the efficient method to machine hard steels and ceramic components with precise components with complex geometry [1–5]. The authors explained about the design of experiments introduced by Taguchi, an orthogonal array of process parameters designed by covering all the levels of input parameters to conduct the experiment efficiently and analyses influence the of performance characteristics (MRR & SR) in terms of voltage, peak current, Interval time and pulse duration [6–10].

Panta Madhu, et al., worked on the aluminium metal matrix nanocomposites in wire EDM machining and optimized the process using VIKOR analysis [3]. The authors discussed the multi-objective optimization in wire EDM machining process and discussed about the influence of

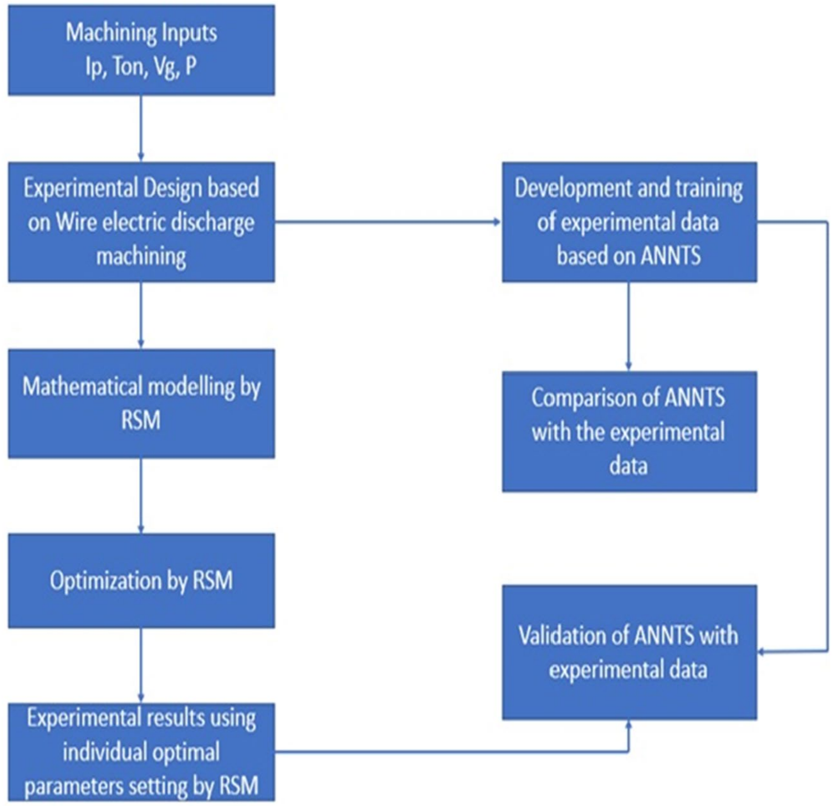

Fig. 1 Flow chart on the method

Table 1 Input variables and its levels

Input variable	Maximum	Medium	Minimum
Peak current	20	15	10
Flushing pressure	1.5	1.0	0.5
Pulse on time	150	100	50
Gap voltage	60	50	40

process parameters, while achieving more than one objective simultaneously [11–15]. In this research the variables such as spark variable gap size and non-uniformity of spark distribution near the wire are considered for analysis to increase the performance of machining in the wire EDM [16–20]. The hybrid method of combining ANN with genetic algorithm is used for the optimization in WEDM process [21–25].

The study on the WEDM process parameters for Aluminium 5454 alloy is carried out by changing the angles of work pieces 30°, 45° and 60° and experiments are performed to provide slots. The taper angle, pulse-off time and peak discharge current are considered as the controllable parameters to obtain the optimum process parameters. Suryapavan Cheruku, et al., developed an algorithm for wire EDM machining of Inconel 718 to reduce the surface roughness and used different techniques like ANN, SVM and GA to predict the surface roughness of Inconel 718 components [8]. Boopathi Sampath, et al., used helium assisted near dry wire cut electric discharge machining (NDWEDM) method molybdenum wire was used to cut M2-HSS material. The dielectric pressurized non-reacting helium gas mixed with minuscule water to form a fluid is used to overcome cooling and flush-out debris. Here, Taguchi method was used to have new experimental set up for WEDM to obtain the optimum parameters [26–30].

Akash Singh, et al., discussed about the manufacturing of aluminium based MMCs in stir casting process and looked over for EDM machining which is used to obtain deep holes and complex contours from the obtained composites. To examine, the obtained parameters grey regression analysis [GRA] was used and compare those with the RSM values. Finally, it was observed that GRA values are better than RSM values [10]. Ramakrishan. R, et al., elaborates the process of optimization in wire EDM process by design of experiments (Taguchi L9 orthogonal array and utilization of different techniques like ANN and MRSN. A good improvement was obtained [11]. For predicting mechanical properties, KNN and ANN algorithms are employed and contrasted. It is quite helpful to save a lot of time and efforts when using machine learning predictions [12].

Table 2 Experimental values of inputs and outputs

I_p	V_g	T_{on}	P	MRR
10	40	50	1.5	0.914356
10	40	100	2	1.663949
10	40	100	1	1.443667
10	40	100	1.5	1.663949
10	40	150	1.5	1.352061
10	50	50	2	0.914356
10	50	50	1	1.663949
10	50	50	1.5	1.352061
10	50	100	2	1.663949
10	50	150	2	0.480952
10	50	100	1	1.777777
10	50	150	1	0.859259
10	50	150	1.5	2.455
10	60	50	1.5	3.375
10	60	100	2	1.18
10	60	100	1	1.797297
10	60	100	1.5	3.368421
10	60	150	1.5	1.411765
20	40	50	1.5	0.433404
20	40	100	2	0.133828
20	40	100	1	0.584407
20	40	100	1.5	0.791050
20	40	150	1.5	2.022939
20	50	50	2	0.265644
20	50	50	1	1.856163
20	50	50	1.5	1.856163
20	50	100	2	1.856163
20	50	150	2	1.856163
20	50	100	1	1.856163
20	50	150	1	1.856163
20	50	150	1.5	1.856163
20	60	50	1.5	1.856163
20	60	100	2	1.856163
20	60	100	1	0.480952
20	60	100	1.5	1.777777
20	60	150	1.5	0.859259
15	40	50	2	2.455
15	40	50	1	3.375
15	40	50	1.5	1.18
15	40	100	2	1.797297
15	40	150	2	3.368421
15	40	100	1	1.411765
15	40	150	1	0.971923
15	40	150	1.5	1.531132
15	50	50	2	1.026213

Objectives

The main objectives of this work is to.

- Minimize surface roughness, Minimize tool wear rate and maximize material removal rate by selecting the proper combination of pulse on time, input peak current and gap voltage.

The overall objectives of this work is to.

- To improve the productivity by proper selection of process parameters by the optimization of process parameters.
- To reduce experimentation time and cost.
- To increase the performance of machining by finding influential parameters on performance characteristics.

Methodology

Figure 1 presents the flow chart on the method. The input variables were input peak current, gap voltage, pulse on time and flushing pressure and the ranges for input parameters were fixed based on limitations of machine manufactures and the input parameter levels are tabulated which is shown in Table 1. The experiments are conducted and the variation of input parameters on tool wear rate, MRR and average surface roughness were investigated. Minitab is used for the analysis and generation of surface plots are carried out to find the influencing parameter on output characteristics.

After the machining process, the output parameters are obtained and shown in Table 2. The obtained valued are utilized to train the ANN model in the python in excel format. Then the accuracy of ANN model is measured and explained using the plot. Then the Minitab is used for Anova analysis and to generate the surface plots for the RSM method.

Results and Discussions

The surface plot graphs of the output variables for MRR, Tool wear rate, and average surface roughness versus various input parameters such as input peak current, gap voltage pulse on time and flushing pressure are plotted and shown in Figs. 2, 3, 4. By observing the surface plots above, it is observed that the pulse on time and peak current are directly proportional to material removal rate, as the pulse on time and peak current increases, there will be increase in MRR which leads to reduction in wire vibration and good accuracy surface finish. Graph refers, increase in removal rate is obtained due to increase in Ip and Ton [31–35]. It can be seen that at some point of gap voltage the MRR is increased then it is reduced, so there should be limit in maintaining gap voltage. In case of surface roughness (Ra), flushing pressure has more influence compared to other input parameters [36–42]. By referring graphs, it is also observed that surface

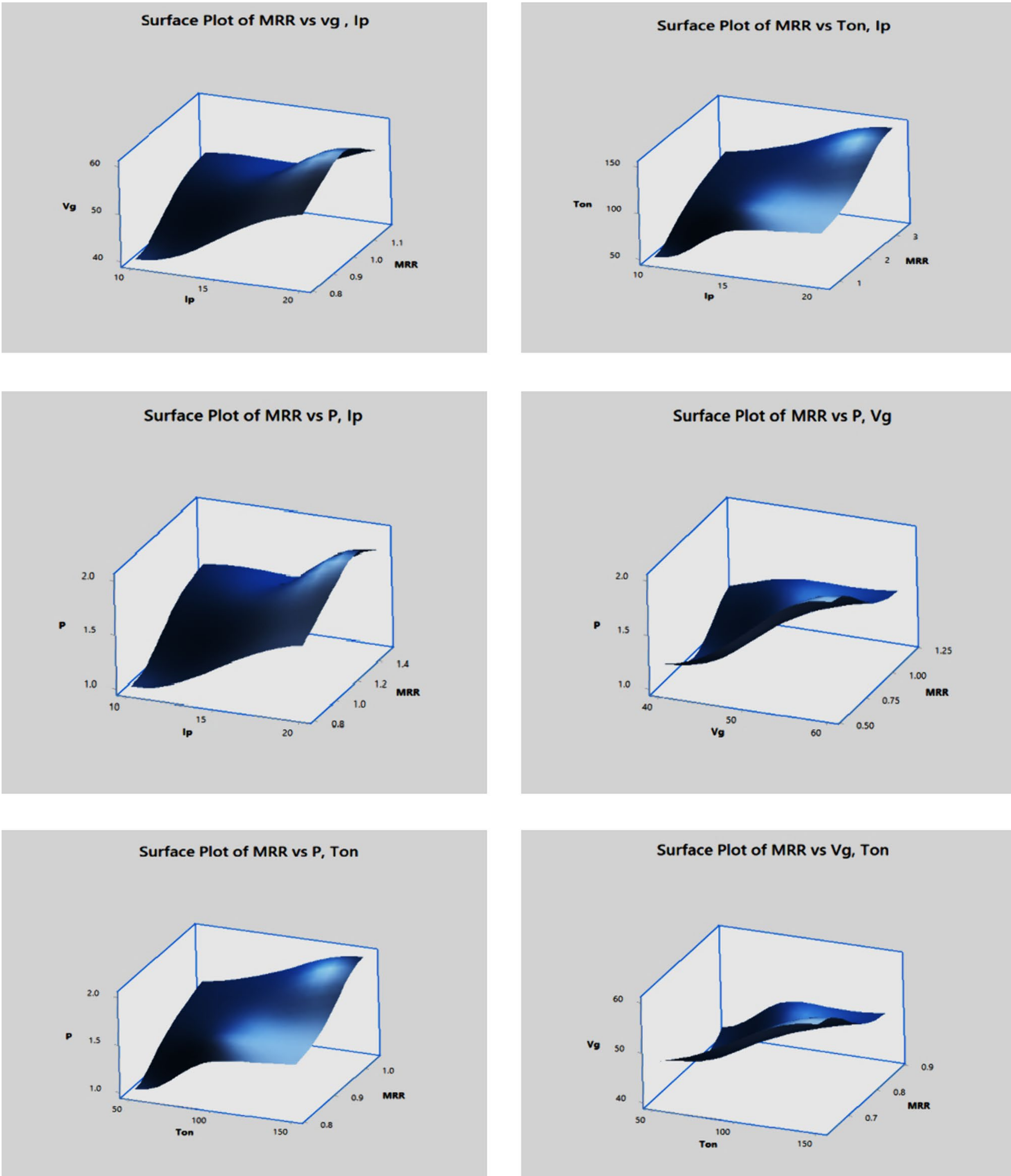

Fig. 2 MRR versus combination of input parameters

roughness improved by variations in pressure. Over all, it is observed that the surface plots with various parameters of input and output determines the relation between them, from which it is able to predict the accurate input values to reduce wire vibration and the proper output [43–50].

The value from Table 2 is given to the artificial neural network modelling and testing using python 3.2. The

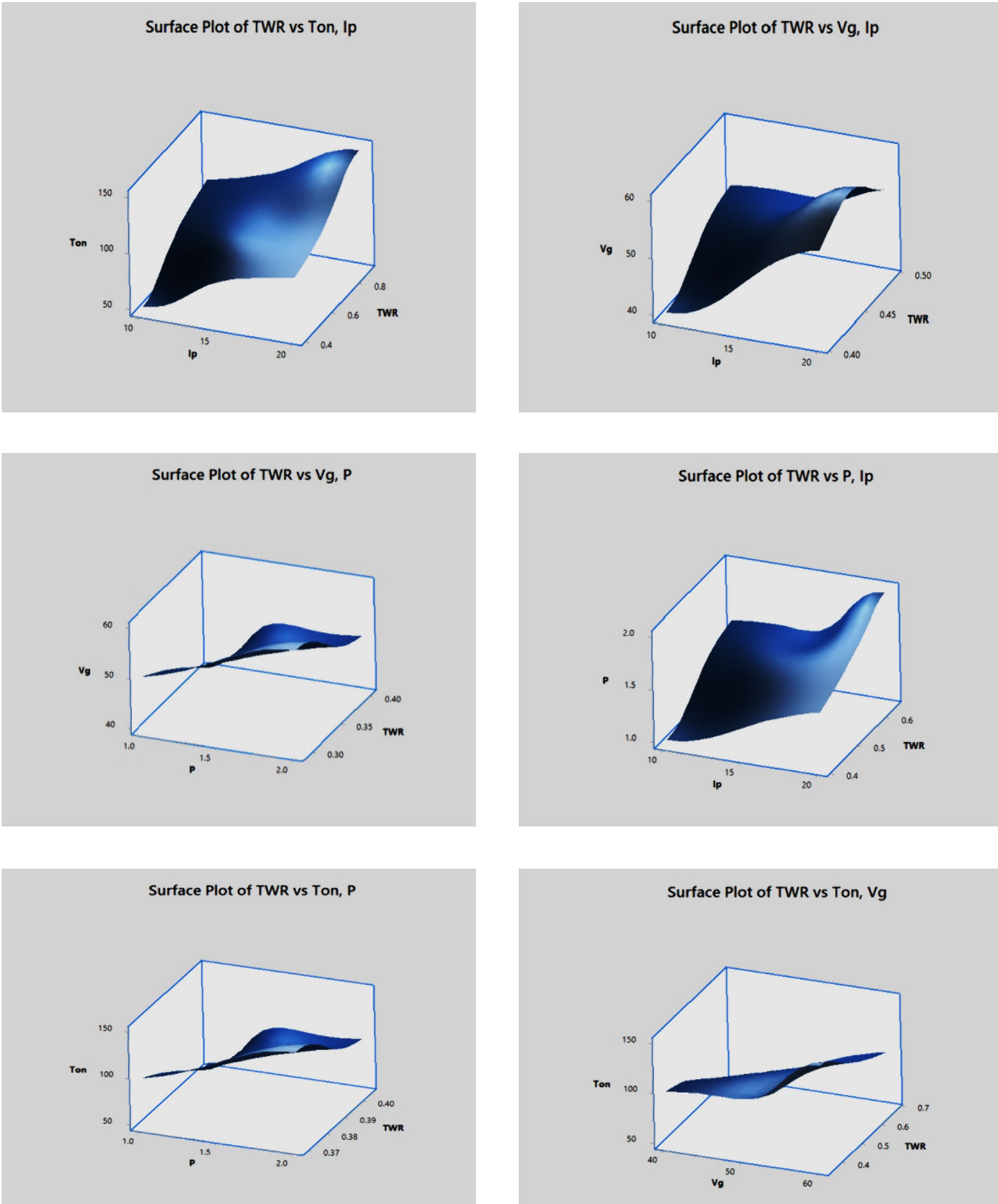

Fig. 3 Tool wear rate versus combination of input parameters

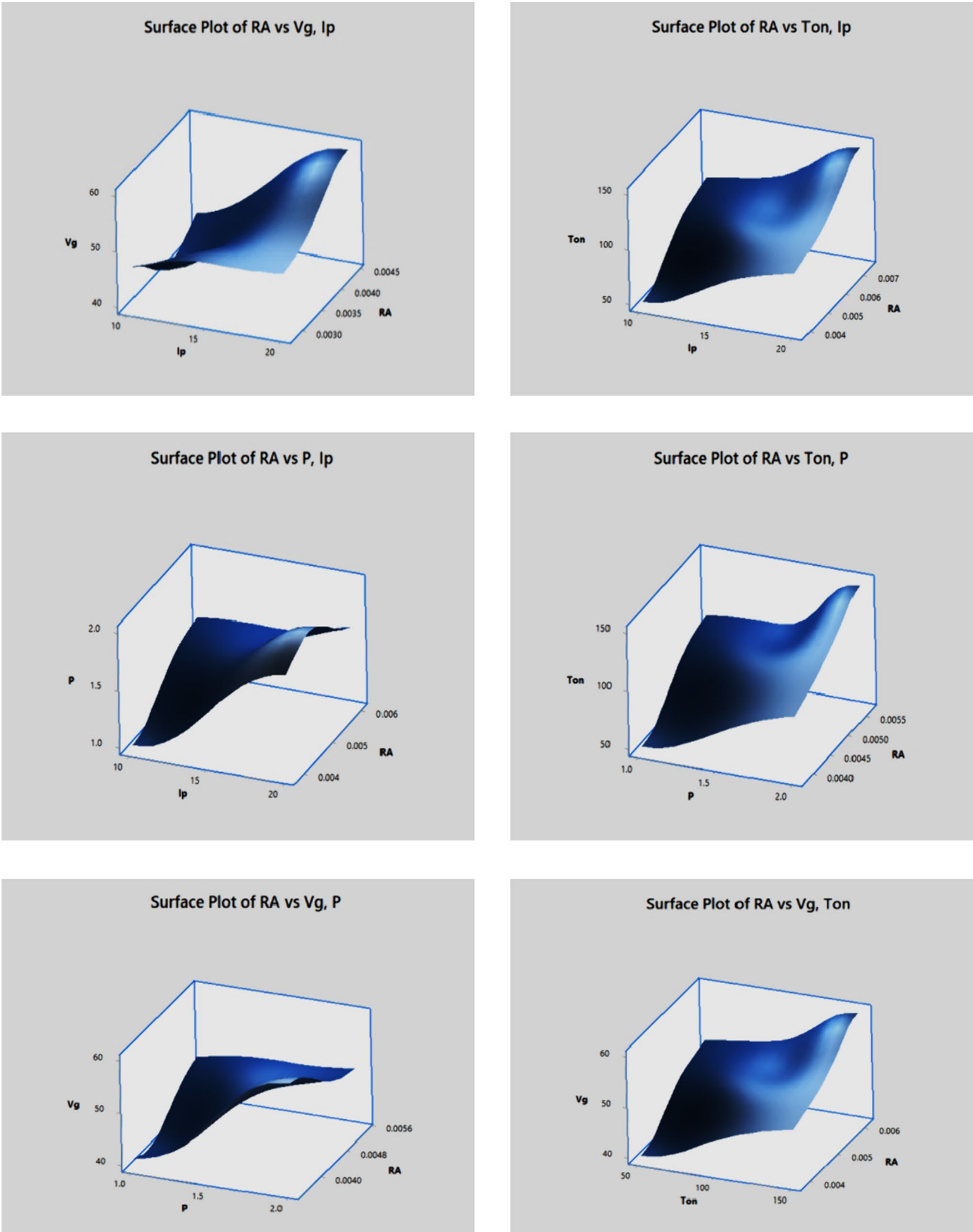

Fig. 4 Average surface roughness versus combination of input parameters

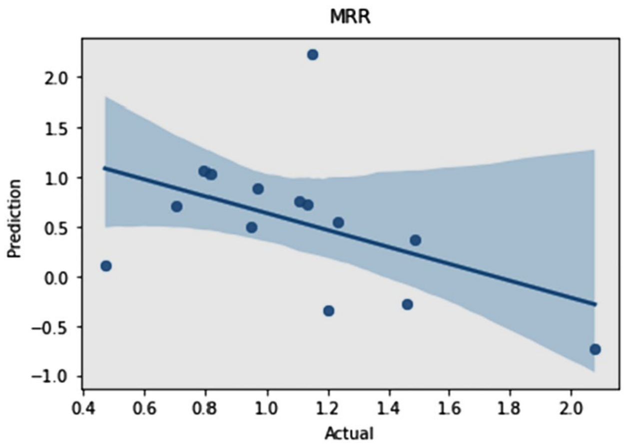

Fig. 5 MRR prediction using ANN versus actual value

predicted material removal rate is plotted against actual values MRR which is shown in Fig. 5 [51–60]. The R-Square value of above model is 84.7. From the graph, it is inferred that most of the predictions are falling under the feasible region of prediction which shows good accuracy of the algorithm [61–70].

Conclusions

In this paper, process optimization on wire EDM machining of A365/WC metal matrix composites is carried out using RSM method and ANN. It is observed that Input current and Ton have more influence on Material Removal rate compared to other parameters. ANN model is developed to predict the MRR value of EDM machining process and accuracy of model is calculated to confirm the proper prediction. The predicted and actual values are compared to find suitable model for engineers for optimization in manufacturing. This work can be extended by applying the similar method to other machining process and also other materials. It also can be investigated using other data analysis techniques to increase the accuracy of predictions made by the techniques.

Funding No funding or other financial assistance were given to this work.

Data Availability Not applicable.

Declarations

Conflict of interest The writers claim that there are not any conflicts of interest.

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