Chapter

Analysis and Optimization of Process Parameters in Wire Electrical Discharge Machining Based on RSM: A Case Study

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Abstract

In this book chapter a review and critical analysis on current research trends in wire electrical discharge machining (WEDM) and relation between different process parameters including pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire speed, wire tension on different process responses include material removal rate (MRR), surface roughness (Ra), sparking gap, wire lag and wire wear ration (WWR) and surface integrity factors was investigated. On the basis of critical evaluation of the available literature following conclusions are summarized. In addition, different modeling and optimization methods used in WEDM were discussed and a case study based on response surface method (RSM) including design of experiment (DoE) carried out to find optimal process parameters effect on surface roughness was conducted. In the final part of the present study was presented some recommendations about the trends for future WEDM researches.

Keywords: optimization, modeling, WEDM, RSM, DoE, surface quality

1. Introduction

The aim of this book chapter is to present some knowledge about the contributions of various researchers on WEDM process and to conduct an optimization approach named response surface methodology to determine the optimal process parameters. In addition, this book chapter is concluded by highlighting the optimal ranges of parameters in WEDM process for various materials and indicating the future research directions which will provide a reference to machine tool operators and manufacturing industries depending upon their demands. Moreover, this paper reviews and examines the various notable works in the field of WEDM and emphasis is made on optimization and modeling of machining parameters. The chapter also explains various advantages and disadvantages of different modeling and optimization methods used, and presents with some recommendations about trends for future WEDM researchers.

WEDM has a key role in unconventional machining method since it facilitates production of certain materials such as zirconium, titanium and intricate shapes. Wire

EDM is a thermo- electrical process which material is eroded by a series of sparks between the work piece and the wire electrode. The part and wire are immersed in a dielectric fluid which also acts as a coolant [1]. In EDM process, wire movement is monitored quantitively to obtain three dimensional shape. EMD has been known for more than a half century and used to manufacture high accuracy of the workpiece in machining processes and metal, tool, die, etc. industries. The development of the WEDM process was the result of seeking a technique to machine the electrodes used in EDM. In the end of the 1970s, computer numerical control (CNC) system was integrated with WEDM process. This integration was brought about a major evolution of the machining process. Moreover, the broad capabilities of the WEDM process were extensively exploited for any through hole machining owing to the wire, which has to pass through the part to be machined. It is probably the most exciting and diversified machine tool adopted for this industry in the last 50 years, and has various beneficial to use. In this process, there is no contact between electrode and work piece. Hence, materials of any hardness can be cut as long as they can conduct electricity. In addition, the wire does not touch the workpiece. So, physical pressure imparted on the workpiece is not exist, and amount of clamping pressure required to hold the workpiece is very low [2, 3]. Schematic diagram of WEDM process is given in **Figure 1**.

Recently, WEDM process has been widely used in manufacturing industry such as metals, alloys, sintered materials, cemented carbides, ceramics and silicon because of making micro-parts. These different systems support WEDM process which has remained as a competitive and reduced cost machining option fulfilling the demanding machining part requirements imposed by the short product development cycles and the growing cost pressures [4]. One of the most widely and commonly used and popular non-traditional material removal procedure which is currently often applied to manufacture components with complex shapes having great accuracy and precision is WEDM. Although, Wire-EDM uses a wire which acts as an electrode which is continuously traveling and is generally made up of thin brass, tungsten or copper, and is having a small diameter of 0.05–0.3 mm. Wire motion is regulated numerically to accomplish converted 3-dimensional shape and high precision of workpiece [5, 6]. Basic uses of wire electrical discharge machining incorporate extrusion tools and die, fixtures and gauges, models, airship and medical parts, and fabrication of stamping,

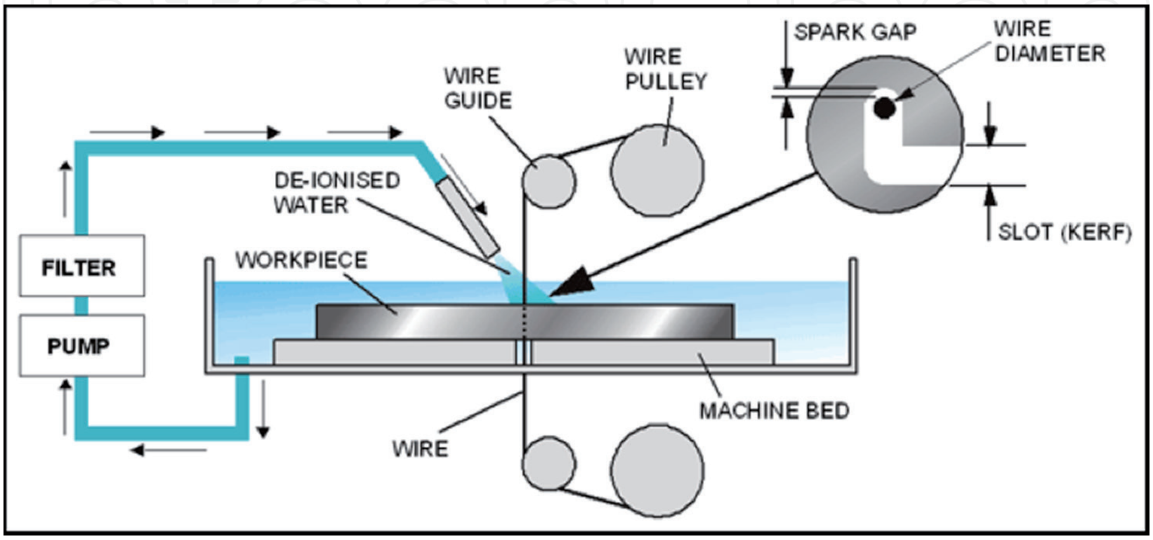

Figure 1.
Schematic diagram of WEDM process.

grinding wheel form tools [7]. Moreover, WEDM has been replacing other traditional machining operations in many industries throughout the world namely drilling, milling, grinding, turning, taper turning, etc. The setting for the various process parameters required in WEDM process play crucial role in achieving optimal performance. The main goals of WEDM manufacturers and users are to achieve a better stability and higher productivity of the WEDM process. Wire electrical discharge machining manufacturers and users emphasize on achievement of higher machining productivity with a desired accuracy and surface finish.

Response Surface Methodology is an important technique to use in designing, formulating, developing, and analyzing for different scientific studies and various industrial products. It is well known optimization method involves mathematical and statistical techniques. In RSM approach the objective is to optimize the response that is influenced by several input variables. Moreover, it is effictive and useful in the improvement and development of existing studies and products. Also, it can be applied to solve the optimization problems in different industries and it is commonly used Biological and Clinical Science, Social Science, Food Science, and Physical and Engineering Sciences. In many different manufacturing industries, one of the important issues is whether the system includes a maximum or a minimum or a saddle point, which has a wide important in industry. Therefore, RSM has been increasingly used in different industries. In addition, in recent years more emphasis has been placed by the chemical and processing field for finding optimal regions where there is an improvement in response instead of finding the optimum response [8]. The first aim for response surface method is to find the optimum response effected various input variables. When there are constraints on the design data, then the experimental design has to meet requirements of the constraints. The second purpose is to evaluate how the response changes in a given direction by adjusting the input and output variables [9, 10]. In generally, conventional data processing methods are not appropriate for investigating the process and product parameters. Many researchers have investigated the suitability of different empirical models to predict the changes in the quality parameters during different drying processes. Based on the function fitting technique, a response surface model in high dimensional space was fitted to show the relation between experiment inputs and output with minimum process knowledge. So, it could be used as an different alternative for conventional models like numerical simulation during optimization with a reduced computational cost and time according to the other various optimization techniques. On the other hand, RSM-based models are only accurate for predicting the relationship between a limited number of input and output parameters. Box-Behnken and central composite design (CCD) commonly used in many research, both have its advantages [11–13].

In this study a predictive model (RS model) is developed and applied to optimize WEDM machining parameters using RSM approach. Experiments are carried out to test the the validity and accuracy of model and satisfactory results are obtained. The methodology described here is expected to be highly beneficial to manufacturing industries such as aerospace, chemistry, textile, automobile and tool making, etc. industries.

2. Literature review: process modeling and optimization

Due to large number of process parameters and responses lots of researchers have attempted to improve the process capability. Some researchers have used different optimization techniques such as Taguchi technique, gray relational analysis

(GRA), design of experiment, artificial neural network (ANN) modeling, desirability approach and evolutionary algorithm. Lots of authors tried to model this process using the Taguchi method and response surface methodology approach [5, 14–18] which utilized response surface methodology coupled with gray-Taguchi technique. Further, Lin [19] have combined Taguchi method with the GRA to optimize the micro milling EDM performance. Similarly, hybrid approach of Taguchi gray has been used by Rajyalakshmi and Ramaiah [20] for multiple performance optimization of WEDM machined Inconel 825. In contrast to WEDM performance evaluation, Sharma [2] have used one factor at a time approach to investigate the effect of various WEDM control parameters on performance characteristics. Except conventional techniques of optimization, some evolutionary algorithm has been in literature such as genetic algorithm (GA), artificial bee colony (ABC), particle swarm optimization (PSO), teaching learning-based optimization (TLBO) and differential evolution (DE). These algorithms provide a global optimum solution instead of local optimum solutions. The parametric settings named optimal solution is found out based on optimization techniques like VIKOR based Harmony search algorithm and desirability function approach to get perfect surface finish during electrical discharge coating and electrical discharge machining of AISI 1040 stainless steel and Nitinol respectively [5]. Further, statistical models have been developed by Kuppan et al. [21] to determine the relationship between EDM output responses and control parameters using response surface methodology. Similarly, Ramakrishnan and Karunamoorthy [22] have developed the mathematical model based on Box and Hunter central composite design to determine the effect of control parameters on EDM performance characteristics. Further, Ramakrishnan and Karunamoorthy [23] presented an Artificial Neural

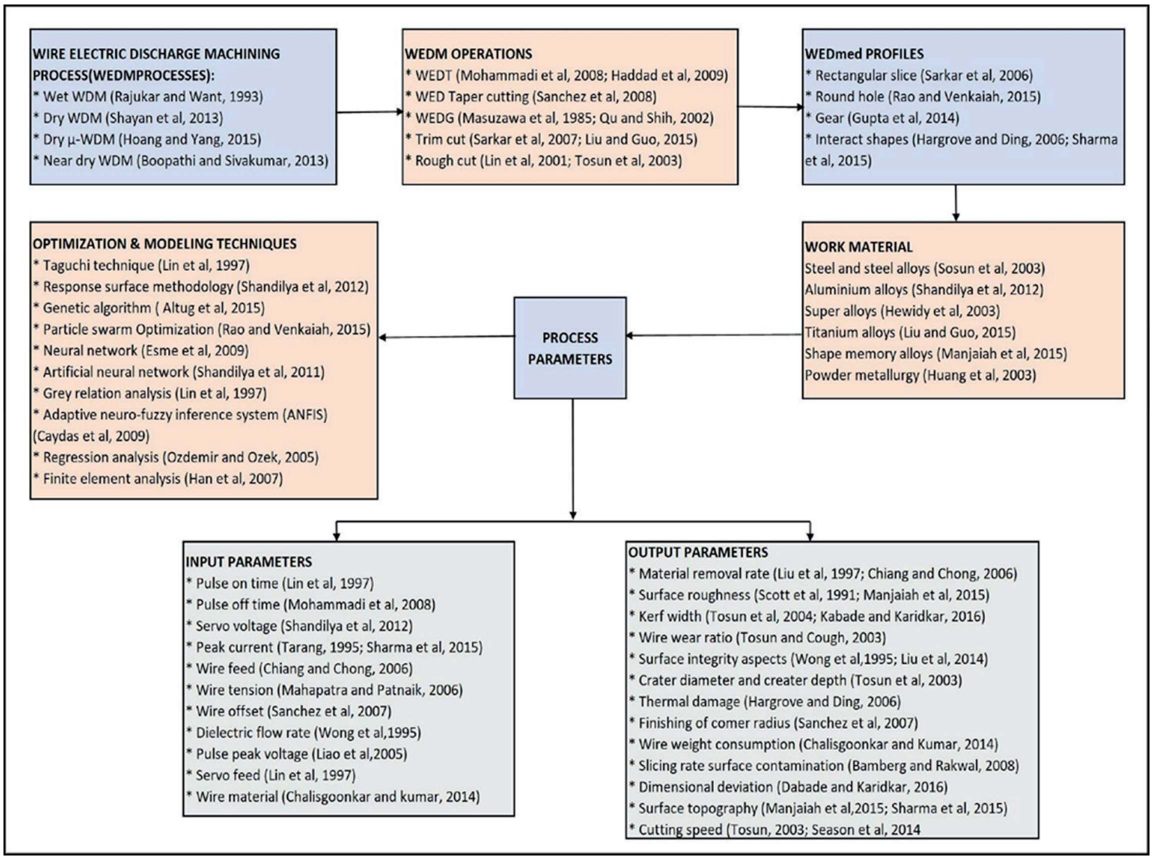

Figure 2.
Comparative study of published research work on WEDM [24].

Network model to predict the WEDM performance of Inconel 718 alloy. **Figure 2** shows a brief outline of past research works.

In cutting operation, WEDM primarily employed either for trim cut [25–27] or rough cut [28, 29]. To the best knowledge of authors, this technique can be successfully employed for machining of steel and steel alloys [30–33] aluminum and aluminum alloys, titanium and its alloys [27, 34] super alloys [35, 36] metal matrix composites [37, 38] green compact manufactured by powder metallurgy [39]. Investigations into the influences of machining input parameters on the performance of WEDM have been widely reported [25, 40–42]. Several attempts have been made to develop mathematical model of the WEDM process [39, 43–47]. In these works, productivity of the process and the surface roughness of the machined work piece are examined as measures of the process performance. Neural network models on material removal rate in EDM has been studied by Tsai and Wang [48] whereas Lee and Li [49] investigated on effects of process parameters in EDM using tungsten carbide as work material. Qu et al. [50] have, through examination of literature, concluded that research has not been directed towards EDM applications in the area of newly developed engineering materials and the boundaries that limit the material removal rate (MRR). Scott, Boyina et al. [43] used a factorial design method, to determine the optimal combination of control parameters in WEDM considering the measures of machining performance as metal removal rate and the surface finish. Tarng and Chung [51] carried out a neural network model to estimate cutting speed and surface finish using input parameters such as pulse duration, pulse interval, peak current, open, servo reference voltage, circuit voltage, electric capacitance and table speed. Trezise [52] presents that essential limits on machining accuracy are dimensional consistency of the wire and the positional accuracy of the work table. Sarkar et al. [25] studied the WEDM of titanium aluminide. They also attempted to develop an appropriate machining strategy for a maximum process yield criterion. A feed forward back propagation neural network was used to model the machining process. Ali [53] investigated on the effect and optimization of machining parameters on the surface roughness in the WEDM process of AlCu-TiC-Si P/M composite. The optimal machining parameters were obtained by using Taguchi experimental design method. The variation of MRR and surface roughness with machining parameters is mathematically modeled by using non-linear regression analysis method. Patil and Brahmankar [54] examined the effect of various input parameters such as pulse on time, pulse off time, ignition pulse current, wire speed, wire tension and flushing pressure on cutting speed and surface finish of Al/SiCp by using Taguchi methods. Shandilya et al. [38] concluded that to achieve higher value of the average cutting speed, lower value of voltage and higher value of pulse-off time should be used during WEDC of SiCp/6061 Al MMC. In the most recent work, They studied the effect of input process parameters on surface surface roughness during WEDM of SiCp/6061 Al MMC. There are some researches that used traditional approach for modeling WEDM like Tarng [51] which utilized feed forward neural network to model and simulated annealing (SA) algorithm is then applied to the neural network to solve the optimal cutting parameters problem. Other one of them is Lin et al. [19] which used Taguchi method with fuzzy logic for modeling and optimization. In addition, Huang [30] studied Wire-EDM based on Gray relational and statistical analyses. Furthermore Kuriakose et al. [55] applied data mining approach. Yuan et al. [56] used incorporating prior model into Gaussian processes regression for WEDM process modeling. Also Caydas, et al. [32] used neuro-fuzzy inference system (ANFIS) to model this process. Besides Cheng et al. [42] utilized a neural network integrated simulated annealing approach for optimizing WEDM. Kapil K. at all [57] investigated the cutting rate and recast layer thickness while designing the servo feed, pulse on-time, servo voltage, and pulse off-time with the Box-Benkhen design of RSM. Kumar et all [45] the Box-Benkhen design of response surface methodology based and machine learning algorithm was applied for the WEDM process, to simultaneously optimize SR, MRR of CP-Ti G2 [58].

3. Case study

In this study, desired surface roughness is obtained based on four input parameters by creating an experimental model of AISI 4030 steel and using response surface methodology. This study has shown that RSM model presented here has overcome WEDM complex that results in satisfactory surface quality characteristics. Each experimental test was conducted twice and averaged as R_a mean values to acquire database with high confidence. Furthermore, experiments were designed using the method that was introduced by Box and Hunter [59]. The experimental runs were performed as per the central composite design which is a type of response surface methodology designs. Response surface methodology has been used to plan and analyze the experiments. CCD was used in order to fit the second order response in surface as well as in optimization methods for finding relation between various individual input parameters and reactions. **Table 1** demonstrates coded value and actual values of individual parameters, and **Table 2** shows machining conditions in WEDM process.

Parameter	**Levels**				
	−2	**−1**	**0**	**1**	**2**
Open circuit voltage (V)	60	120	180	240	300
Wire speed (m/min)	2	4	6	8	10
Dielectric flushing pressure (kg/cm^2)	6	9	11	14	16
Pulse duration (ns)	10	37	50	725	900

Table 1.
Experimental factors and factor levels.

Workpiece	**AISI 4340**
Electrode	CuZn37
Workpiece dimensions (mm)	150 × 150 × 10
Table feed rate (mm/min)	8.2
Pulse interval time (s)	18
Wire diameter (mm)	0.25
Wire tensile strength (N/mm^2)	900
Cut-off length (mm)	0.8

Table 2.
Machining conditions in WEDM process.

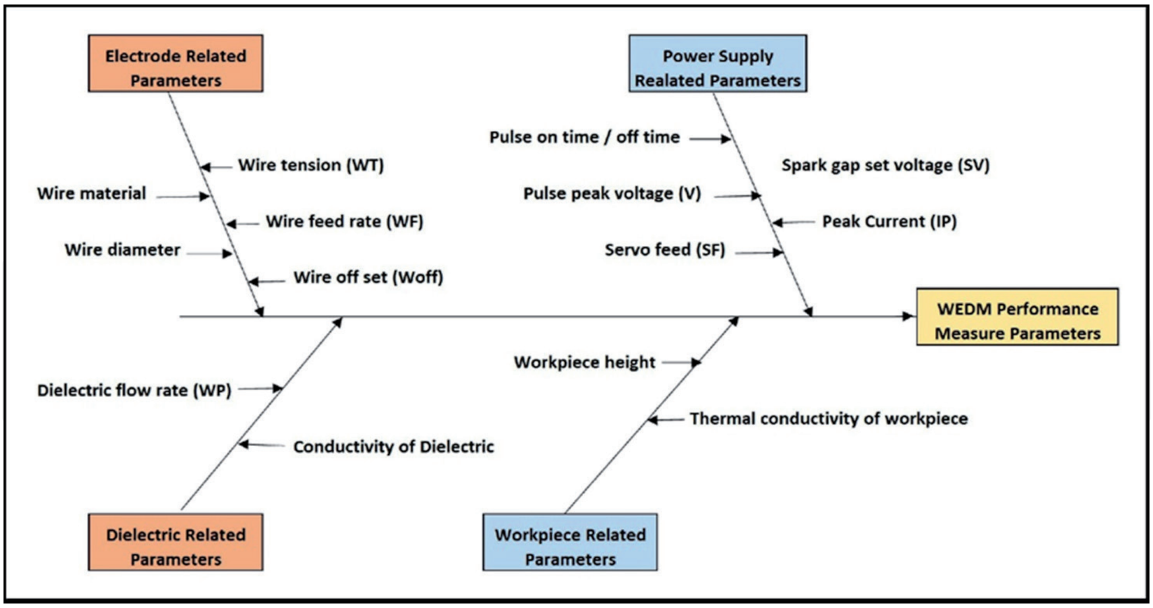

Figure 3.
Cause and effect diagram for WEDM process parameter [24].

3.1 Process parameters used in study

The most important performance measures in WEDM are metal removal rate, surface finish, and cutting width. They depend on machining parameters like discharge current, pulse duration, pulse frequency, wire speed, wire tension and dielectric flow rate. In WEDM process, it is seen that, input process parameters such as pulse-on time, pulse-off time, servo voltage, peak current, wire feed rate, wire tension, wire offset, water pressure, servo feed, wire material are having significant influence on process parameters named surface roughness, kerf width, material removal rate, wire wear rate, surface integrity aspects, etc. [3–9, 16–18]. The various input process parameters of WEDM and their inter-relationship is presented using Ishikawa's cause-effect diagram shown in **Figure 3**.

In this study, open circuit voltage, wire speed, and dielectric flushing pressure were selected as input parameters and surface roughness was selected as output parameter.

3.2 Statistical analysis and modeling using RSM

In Response surface methodology approach responses of interest is influence by several variables and in which the objective is to optimize these responses [59, 60]. In this method the effects of the noise factors have been considered. In addition, statistical optimization model can overcome the limitation of classical methods to obtain the optimum process conditions. Predictive model (RS model), which is an analytical function, in predicting response surface is formulated as following polynomial function:

$$Y = a_0 + \sum_{i=1}^{n} a_i X_i + \sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij} X_i X_j + \ldots + \varepsilon \tag{1}$$

where Y is the desired response, a_0 is constant, a_i and aij represent the coefficients linear, quadratic terms, respectively, X_1 reveals the coded variables corresponding to the studied machining parameters, input variables, n is the number of the model parameters, ε is the random error.

In this study, a predictive model was developed to reach low surface roughness in terms of cutting parameters for milling operations. RSM design was tested with 30 data sets of central composite design of experiment. Surface roughness (R_a) measurements were made by using Phynix TR–100 portable surface roughness tester. Surface roughness measurements were made by using Phynix TR–100 portable surface roughness tester. To identify the significant factors for WEDM process, analysis of variance (**Table 3**) was employed by using Design Expert software.

This table demonstrates that the terms in the model have a significant effect on the responses. It is found that, the open circuit voltage has the most dominant effect on the surface roughness followed by the pulse duration and wire speed respectively. Goodness of fit for model generated by experimental data was evaluated and analyzed based on ANOVA. This includes the tests for significance of model, their coefficients and lack of fit model adequacy. ANOVA is used to create, access and analyze the experimental test data and goodness of fit model is generated afterwards. Through the backward elimination process, the final quadratic models of response equation in terms of coded factors are as follows:

$$\begin{aligned} Y = {} & 114 + 17.73\,X_1 + 3.27\,X_2 + 1.27\,X_3 + 3.47\,X_4 + 15.85\,X_1\,X_2 - 2.65\,X_1\,X_3 - 3.30\,X_1\,X_4 \\ & + 0.91\,X_2\,X_3 + 8.019\,X_2\,X_4 - 1.36\,X_3\,X_4 - 0.75\,X_1^2 - 0.111\,X_2^2 + 0.15\,X_3^2 - 0.44\,X_4^2 \end{aligned} \qquad (2)$$

When the regression model above is examined, change in wire speed has significant impact on surface roughness. In this context, as wire speed increases, increase in surface roughness is observed. There is a strong linear relationship between the surface roughness and open circuit voltage, whereas there is a weak relationship between dielectric flushing pressure between surface roughness. It proves the complex influence of the adopted input variables on the analyzed value of the surface roughness. This model includes experimental test data that shows models importance, coefficients, and inadequacy in model fit.

In this study experimental surface roughness values were compared with surface roughness predicted values of the RS model. It was observed that the prediction of surface roughness closely agrees with that of the experimental values. Moreover, measured surface roughness has been correelated well with the predicted surface roughness values. It was also found that the RS model for the predicted values generates an average best fit percentage error of 6.83%. The involvement of process factors on surface roughness for WEDM process was analyzed with the help of surface graphs for the selected process factor combinations are presented in **Figures 4**–**15**. **Figures 4** and **5** represent interaction graphs wire speed between open circuit voltage and open circuit voltage between dielectric flushing pressure graphs respectively.

Figure 4 shows that at lower wire speed the effect of open circuit voltage on surface roughness is statistically insignificant. However, at higher wire speed the effect of open circuit voltage on surface roughness is important and statistically significant. Similarly, with the rise in wire speed value, the lower value of open circuit results better surface roughness.

It is demonstrated that in **Figure 5**, at lower or higher open circuit value the effect of dielectric flushing pressure on surface roughness is very poor. **Figures 6** and **7** represent interaction graphs wire speed between pulse duration and dielectric flushing between pulse duration graphs respectively.

As seen in **Figure 6** at lower pulse duration the effect of wire speed on surface roughness is not statistically important, whereas, at higher pulse duration level this effect partly more significant. When the wire speed increases at low pulse duration

Source	Sum of squares	df	Mean Square	F-value	p-value
Model	13,239.59	14	945.68	37.98	< 0.0001
X_1- Open circuit volt	7211.01	1	7211.01	289.58	< 0.0001
X_2- Wire speed	256.96	1	256.96	10.32	0.0058
X_3- Dielectric flush. pr.	38.43	1	38.43	1.54	0.2332
X_4- Pulse duration	288.36	1	288.36	11.58	0.0039
X_1X_2	4021.78	1	4021.78	161.51	<0.0001
X_1X_3	112.20	1	112.20	4.51	0.0508
X_1X_4	174.17	1	174.17	6.99	0.0184
X_2X_3	13.27	1	13.27	0.5328	0.4767
X_2X_4	1072.40	1	1072.40	43.07	< 0.0001
X_3X_4	29.40	1	29.40	1.18	0.2943
X_1^2	15.76	1	15.76	0.6329	0.4387
X_2^2	0.3427	1	0.3427	0.0138	0.9082
X_3^2	0.6232	1	0.6232	0.0250	0.8764
X_4^2	5.54	1	5.54	0.2223	0.6441
Residual	373.52	15	24.90		
Lack of fit	318.50	10	31.85	2.89	< 0.0001
Pure error	55.02	5	11.00		< 0.0001
Cor total	13,613.11	29			< 0.0001

Table 3.
The analysis of variance (ANOVA) on the performance of surface roughness.

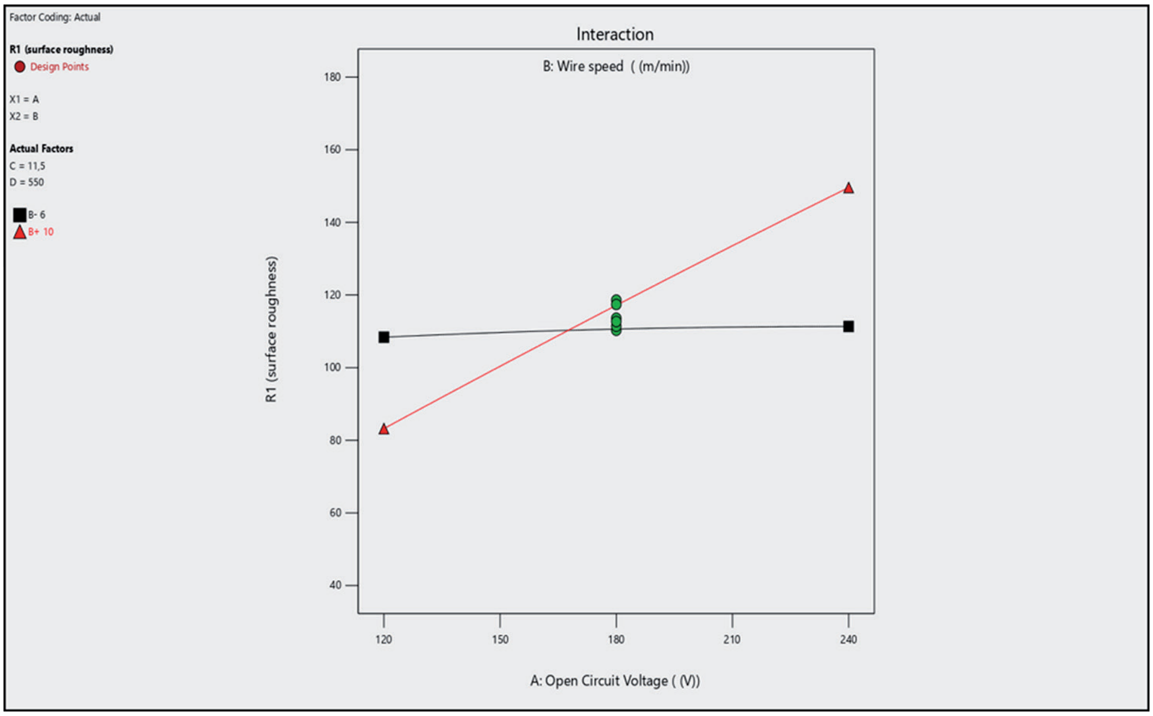

Figure 4.
Interaction graph wire speed and open circuit voltage on surface roughness.

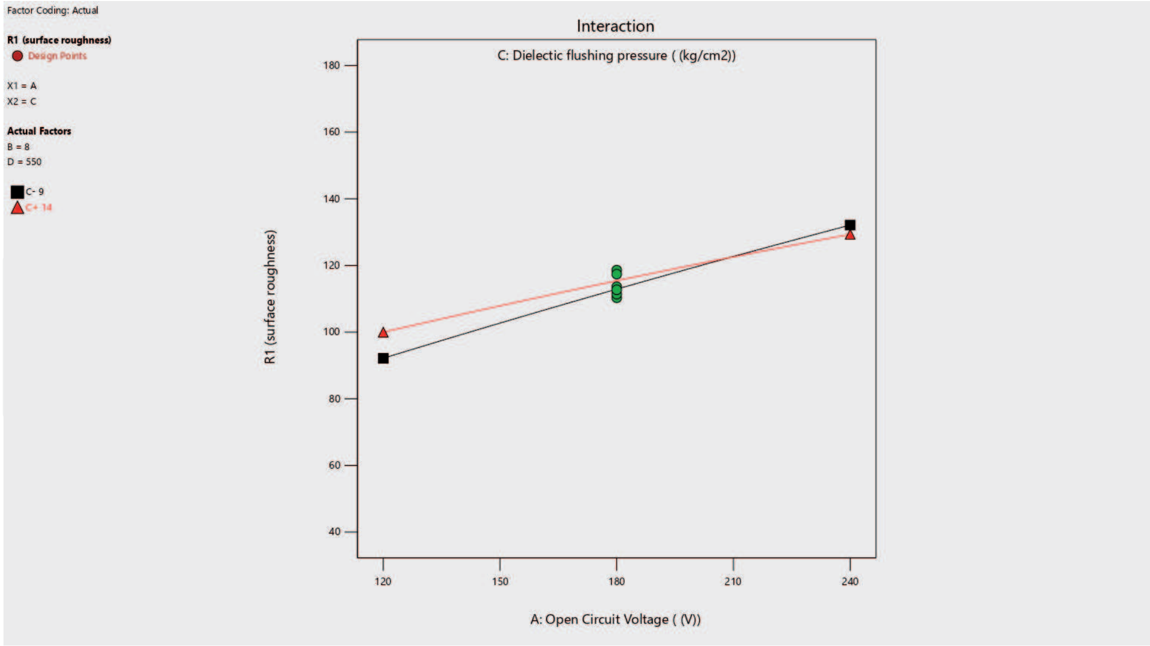

Figure 5.
Interaction graph open circuit voltage and dielectric flushing pressure on surface roughness.

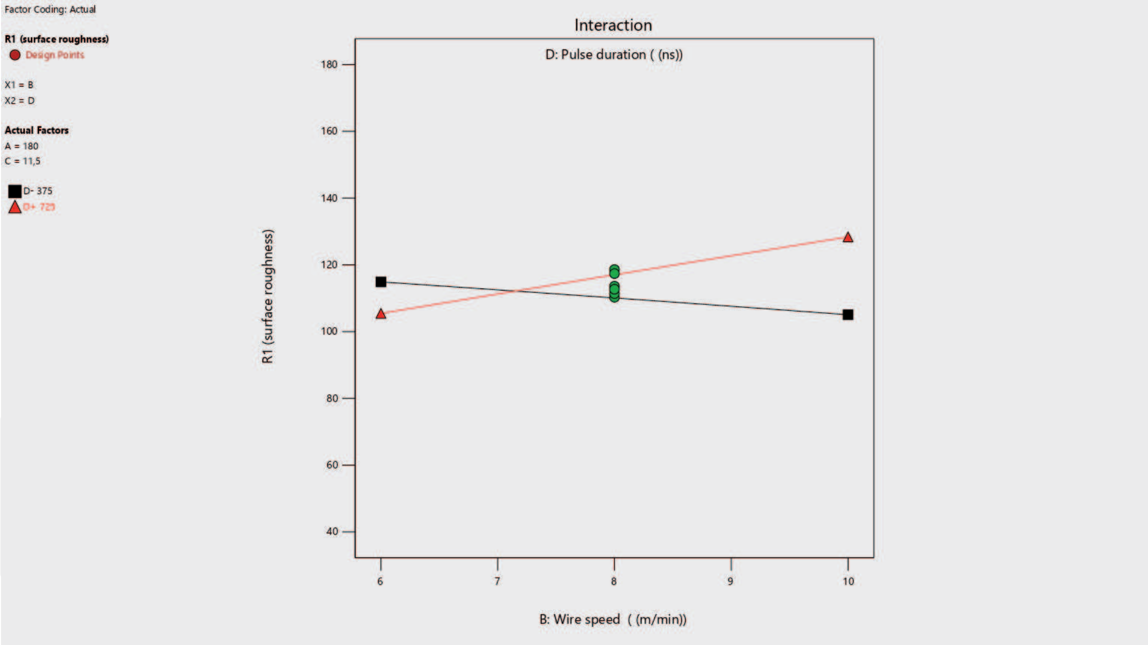

Figure 6.
Interaction graph wire speed between pulse duration on surface roughness.

value surface roughness increases. **Figures 7** and **8** show that the interaction graphs dielectric flushing pressure between pulse duration and dielectric flushing pressure between wire speed graphs respectively.

Figure 7 exhibits that the increasing and decreasing dielectric flushing pressure and pulse duration values it has no statistically significant effect on surface roughness. In **Figures 8** and **9** they are represented the interaction graphs wire speed between dielectric flushing pressure and open circuit voltage between pulse duration graphs respectively.

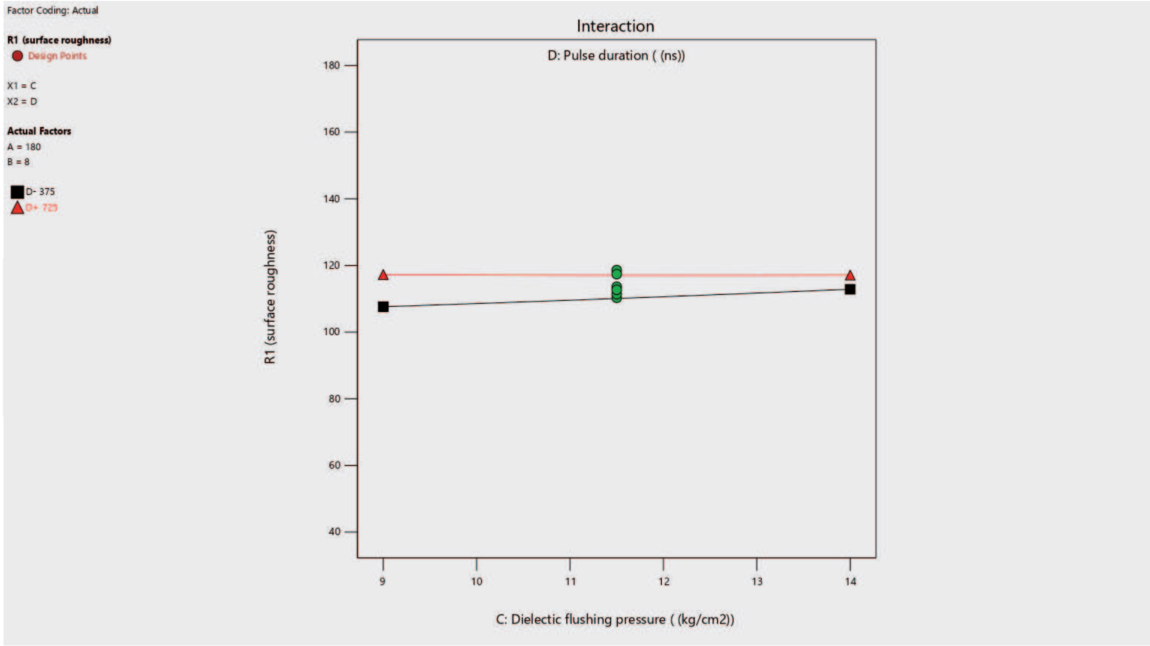

Figure 7.
Interaction graph dielectric flushing pressure between pulse duration on surface roughness.

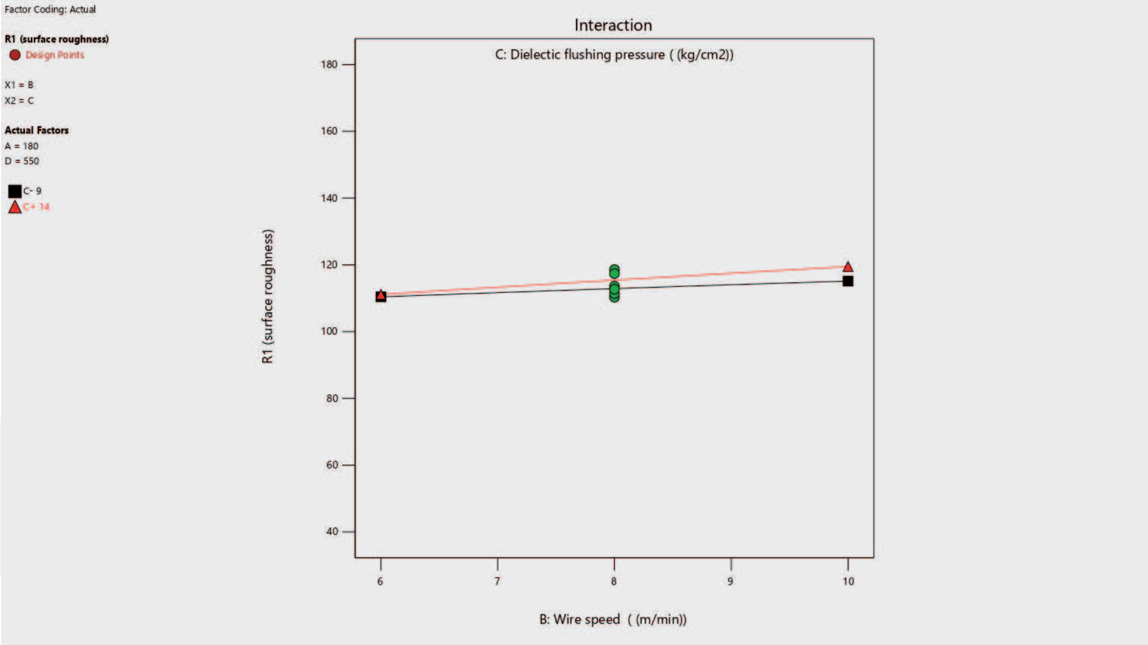

Figure 8.
Interaction graph wire speed and dielectric flushing pressure on surface roughness.

As seen in **Figure 8** in case of increasing or decreasing wire speed and dielectric values the magnitude of the surface roughness does not change significantly in level of significant 5%.

Figure 9 demonstrates the variation of pulse duration and open circuit voltage concerning the surface roughness. It can be causes that increasing surface roughness with the increase in pulse duration when the open circuit increases. Similar trends were observed that lower pulse duration the effect of open circuit on surface roughness is poorer statistically. **Figures 10–15** represent 3D contour plot graphs input and

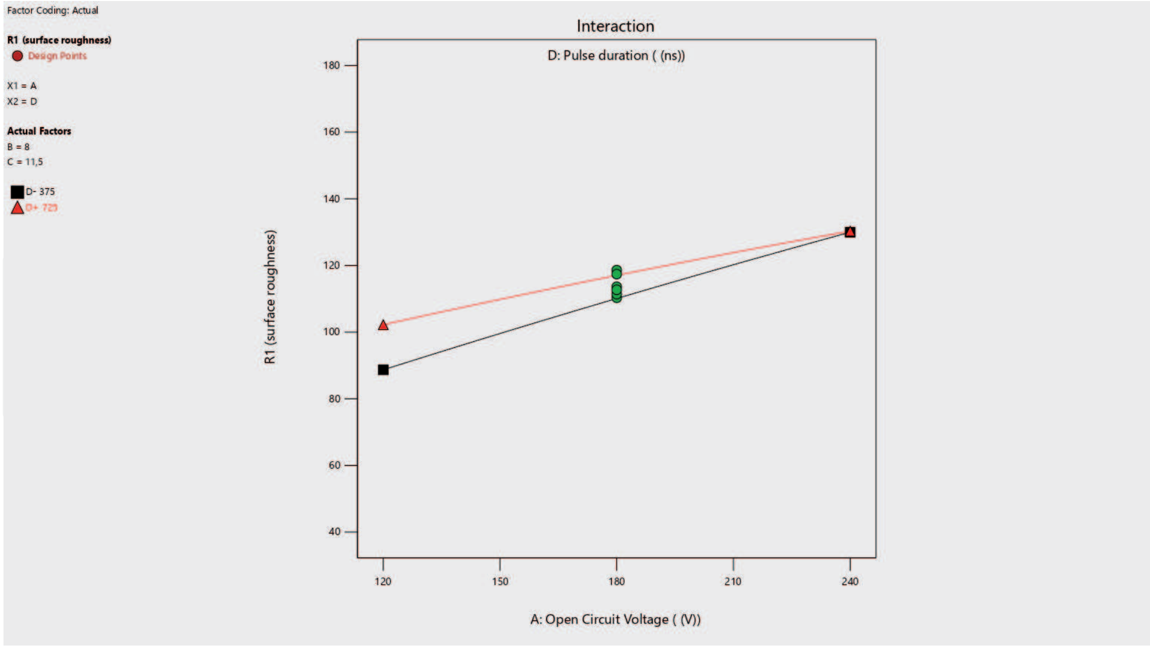

Figure 9.
Interaction graph open circuit voltage and pulse duration on surface roughness.

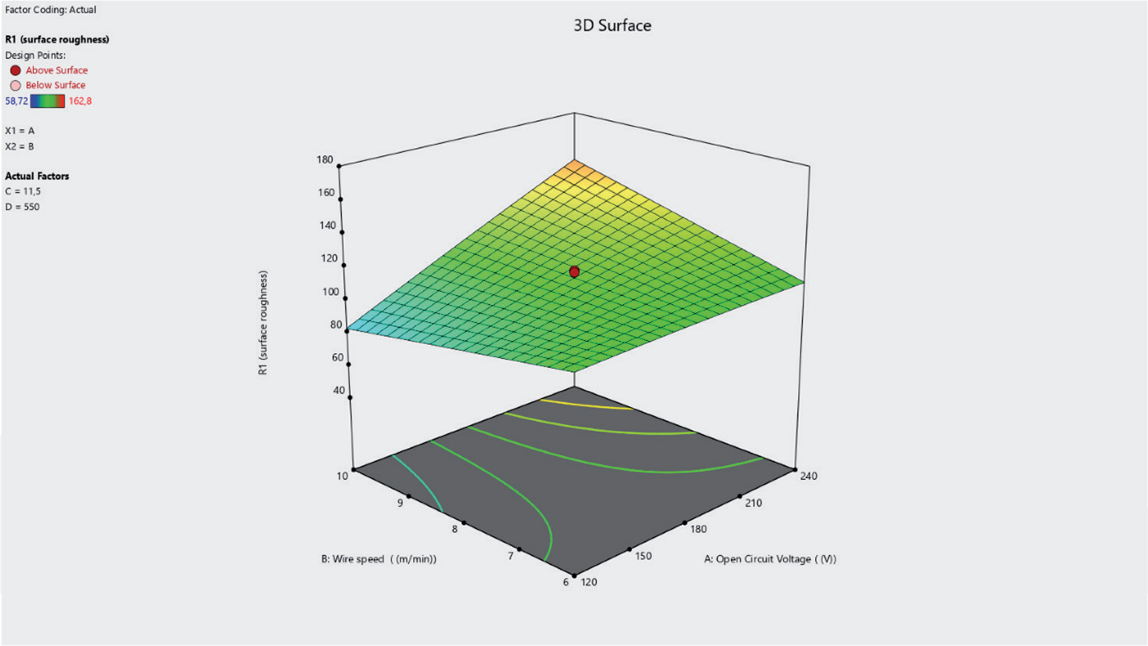

Figure 10.
Contour plot graph wire speed and open circuit voltage on surface roughness.

response variables. **Figures 10** and **11** represent 3D contour plot graphs wire speed between open circuit voltage and open circuit voltage between pulse duration graphs respectively.

As seen in **Figure 10** it was identified that the higher wire speed with the lower open circuit value results better surface roughness. Moreover, when wire speed is increased in case of lower open circuit voltage the value of surface roughness is very poor.

Figure 11 exhibits the surface roughness decreases with an decrease in open-circuit voltage and increase pulse duration. Also, higher pulse duration with lower open circuit voltage the value of surface roughness is minimum. **Figures 12** and **13**

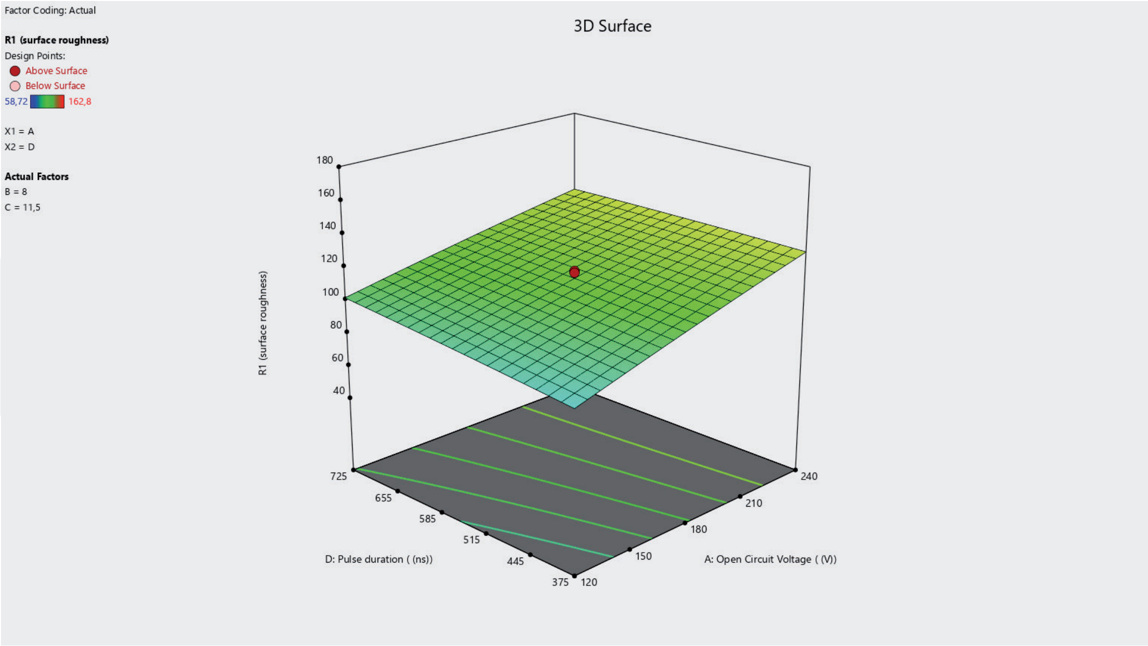

Figure 11.
Contour plot graph pulse duration and open circuit voltage on surface roughness.

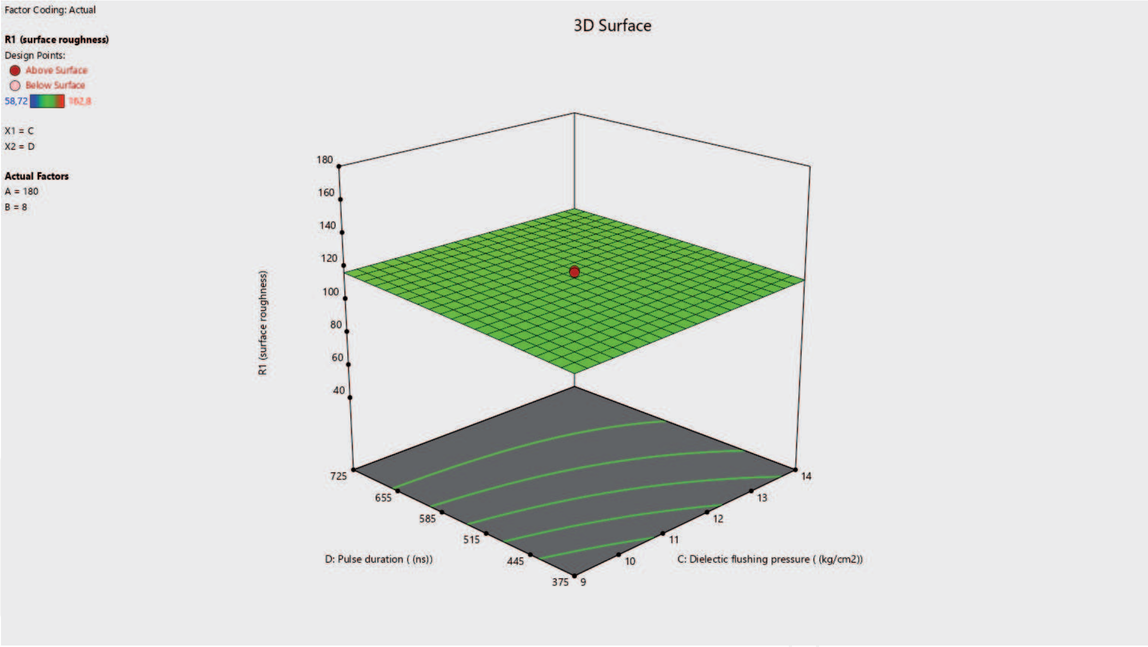

Figure 12.
Contour plot graph pulse duration between dielectric flushing pressure on surface roughness.

represent pulse duration between dielectric flushing pressure and wire speed between dielectric flushing pressure 3D contour plot graphs respectively.

It was noticed from **Figure 12** the lower magnitude of dielectric flushing pressure in case of lower wire speed value decreases surface roughness. **Figures 13** and **14** represent dielectric flushing pressure between wire speed and pulse duration between wire speed 3D contour plot graphs respectively.

As seen in **Figure 13** if dielectric flushing pressure is increased when wire speed is decreased, decreasing in surface roughness is observed. It was perceived that when the higher value of dielectric flushing pressure in case of lower wire speed the value of surface roughness is very poor.

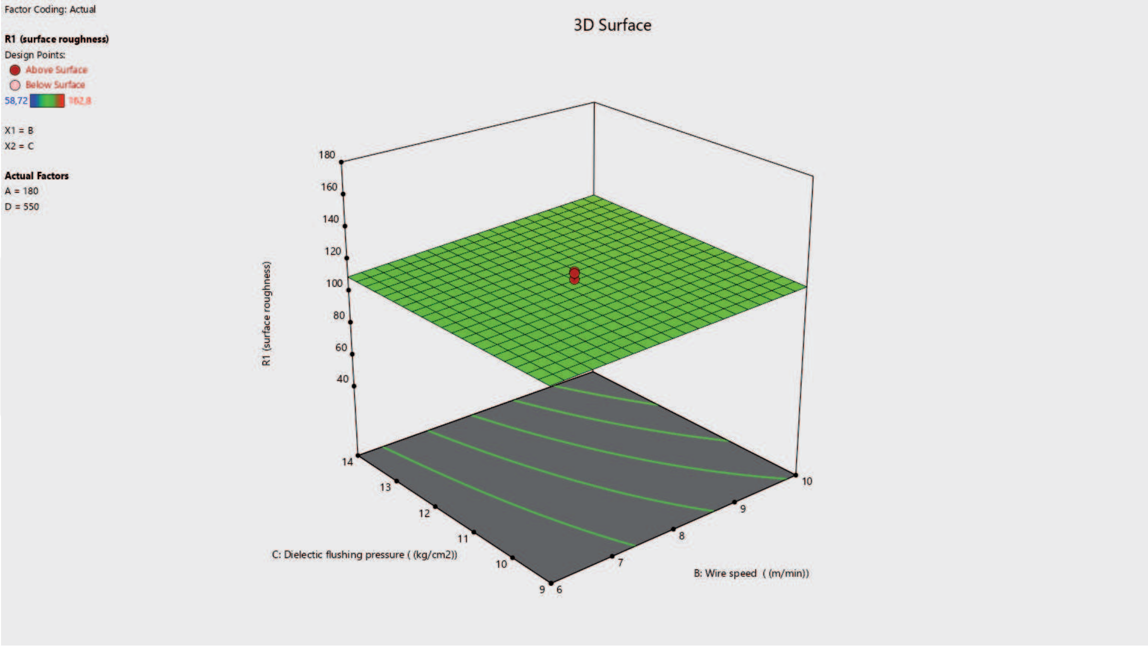

Figure 13.
Contour plot graph wire speed and dielectric flushing pressure on surface roughness.

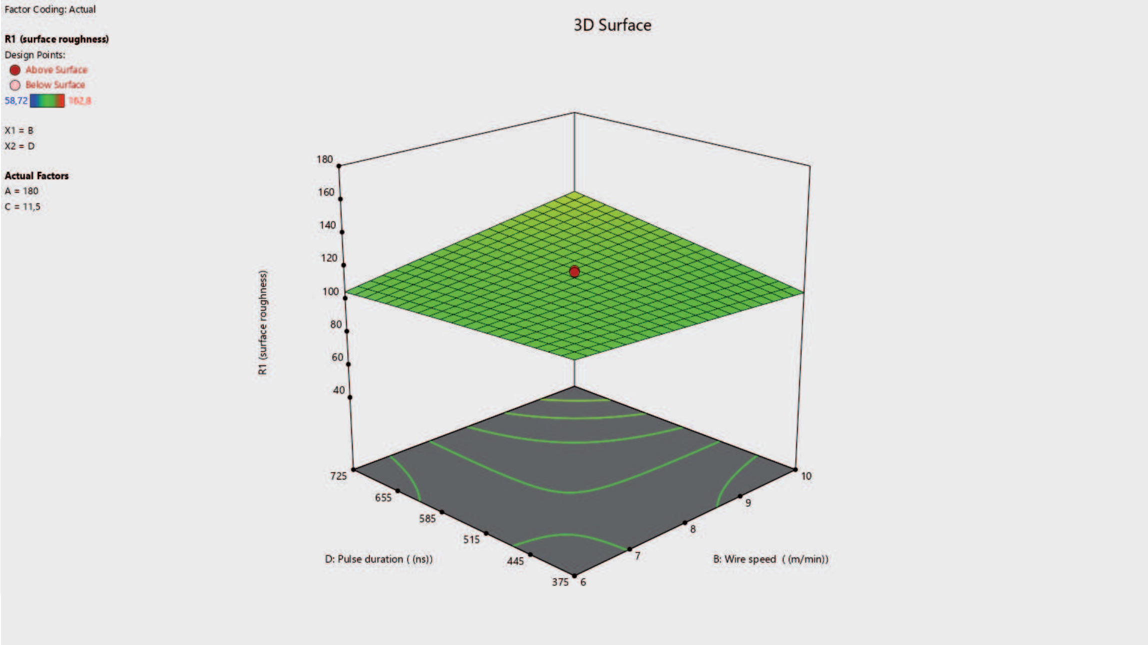

Figure 14.
Contour plot graph wire speed and pulse duration on surface roughness.

Figure 14 shows that at low wire speed with low pulse duration surface roughness value increases. The low values of dielectric when higher pulse duration may cause surface roughness also reduces. In addition, it is predictable from **Figure 14**, the combination of pulse duration and dielectric in lower range gives a good surface finish. **Figure 15** represents dielectric flushing pressure between open circuit voltage 3D contour plot graph.

From **Figure 15** with the increase in wire speed in case of lower open circuit voltage, it can be obtained lower surface roughness. Furthermore, increasing of high of dielectric flushing pressure in case of lower dielectric leads to decreasing surface roughness in WEDM process.

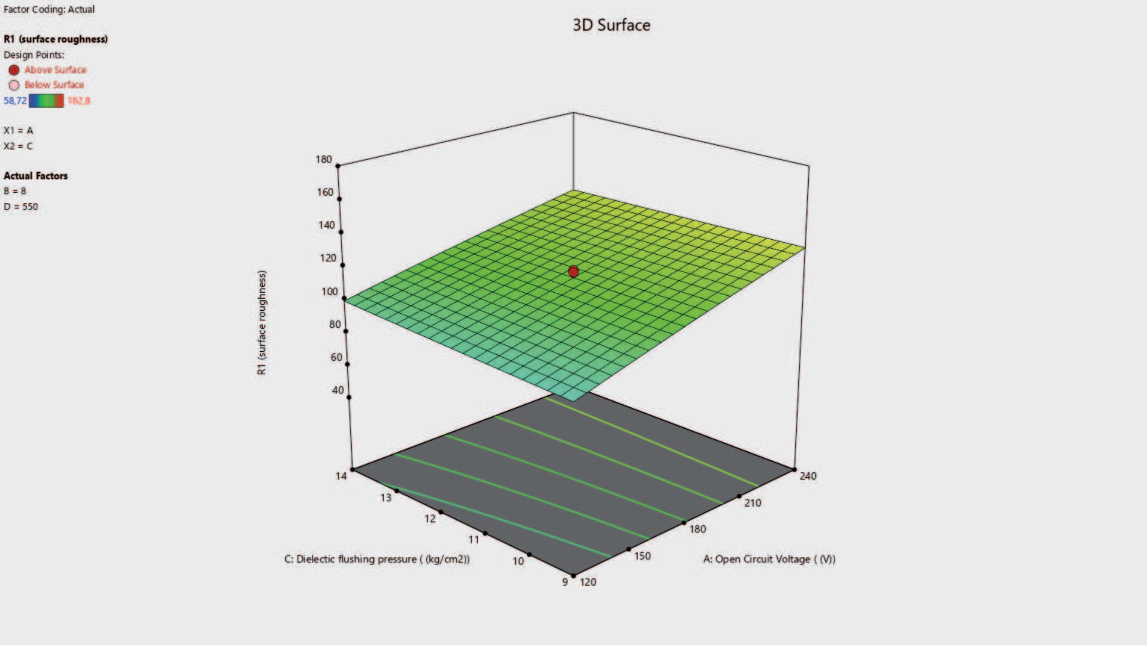

Figure 15.
Contour plots graph dielectric flushing pressure and open circuit voltage on surface roughness.

It is evident that, a predicted optimum surface roughness obtained from the response surface and contour plots by using RSM, a pulse duration of 346 (ns), open circuit voltage of 142 (V), wire speed of 8 (m/min) and dielectric flushing pressure of 12 (kg/cm^2) is 2.63(μm). The objective of developed model is to establish the quantitative relationship between output and input control parameters. It is seen that, RSM model proposed here in has resolved the complex of WEDM process that results in satisfactory surface quality characteristics. Hence, the experimental results confirm that the developed model predicts effectively and the optimal process parameters significantly improve in the WEDM process. As a result, predicted optimum surface roughness was acquired. Results from the adopted design of the experiment, where the explanatory variables were determined independently of each other, is a desirable feature because it indicates the uniqueness of the prediction.

4. Conclusions and future scope

This study mainly focuses on the development of empirical model of AISI 4340 steel in WEDM process to obtain the desired surface roughness in terms of four prominent input parameters using response surface methodology. In WEDM process, optimization of the response variable is very important and essential problem for various scientific studies and manufacturing industries. Because WEDM is an expensive production process and widely used in many manufacturing process such as aerospace, chemistry, textile, automobile and tool making industries. The essential purpose of the WEDM process is to achieve an accuracy and efficiency in production process. Several researchers have studied with different methods to improve the surface quality and increase the material removal rate of the WEDM process. However, the problem of selecting the cutting parameters in the WEDM process is not completely solved. Still there is lack of information about different WEDM wire types. Hence, more research should be done about comparing different inputs on different responses. Finally, it seems that more researches can be strength the capabilities of WEDM process significantly to improve the machining productivity, accuracy and efficiency. From literature review it is obvious that most of the researchers examined lots of number of process parameters at a time to model and optimize various responses, which may not yield accurate optimal values for the process. Further, most of the researchers include both academics and applicants have given the importance to individual and multi -response modeling and its optimization. The proposed RSM approach can effectively assist engineers in determining the optimal process parameter settings for WEDM process for individual response variable. In the future, many studies should be made to investigate the process capability during WEDM of powdered products and multi response optimization on WEDM process by using integrated optimization methods.

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