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Optimization of control factors for EN-42 on WEDM using Taguchi method

Azad Kumar[#*], Jitender Panchal[#] and Deepak Garg^

[#]Department of Mechanical Engineering, MIET, Haryana, India
^Department of Mechanical Engineering, Mahabir Engineering College, Ambala, India

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Abstract

EN-42 offers a variety of advantages over its counterparts such as better stability after hardening, compressive strength, non-deforming properties, and good wear resistance. Due to these properties it is gaining application in manufacturing of laminated spring for railway vehicle, spring washer for used in auto industries, leaf and coil springs. In this study, an attempt has been made to machine EN-42 using wire electric discharge machining. The objective is to investigate the influence of process parameters namely pulse on time; pulse off time, peak current and wire feed on cutting rate and surface roughness. Wire breakage is a problem that constraint the productivity achieved during WEDM process. Wire breakage is directly governed by the discharge energy subjected on the work piece. Discharge energy is influenced by levels of process parameters. Moreover, the influence of process parameters on productivity and accuracy aspects is material dependent. Therefore, preliminary study is carried out to sort out the significant process parameters affecting the cutting rate as well as to identify the operating levels of process parameters. The operating range identified through preliminary study for pulse on time is from 105 µs to 120 µs, pulse off time from 30 µs to 45 µs, peak current from 70A to 130A and wire feed from 6 m/min to 9 m/min respectively. To investigate parametric influence on response parameters, a Taguchi methodology is used to plan and analyze the experiments. The mathematical relationships between WEDM input process parameters and response parameters are established to determine optimal values of cutting rate and surface roughness mathematically

Keywords: *WEDM, Energy-saving pulse power, Energy utilization rate, Energy consumption analysis*

Introduction

Wire Electrical Discharge Machining is the process by which material is wear off with the support of a series of sparks between the tool and work piece. The work piece and the wire are covered in the dielectric fluid which also takes as a coolant and wash out the debris.

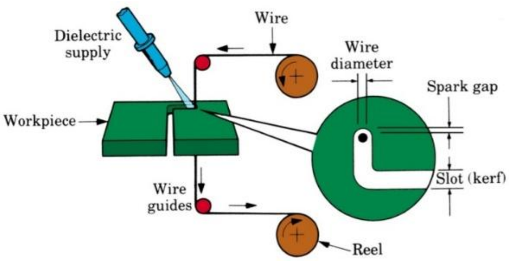

Figure1: WEDM cutting process

The progress of wire is handling numerically to acquire the required three dimensional shapes and the high rate of accuracy of the work piece. WEDM consists of different number of process parameters, so it is difficult to get a best combination of optimum parameters which gives higher accuracy. By using Taguchi method optimization of a single response is often carried out. This method results in the solution which gives best value of each response. Figure 1.1 shows about the general application of the wire EDM cutting process.

Wire EDM, is not a new type of machining, it was invented in the latish1970s', and has done revolution changed in the tools and dies industries. This is the important wide range cutting machine formulated for this sector in the past years. In that process, no physical connection between work piece and tool, so the materials of any hardness can be easily cut if they are electrically conductive. Since the wire not strike the workpiece, so that no pressure apply on the workpiece and clamping pressure required to maintain the workpiece is less. The electrical conductivity is an important factor in this type of machining few methods are used to increase the effectiveness of the machining of less electrical conductive materials. The Spark Theory on the wire EDM is identical to the vertical EDM process. Many sparks can be analyzed at one time. The temperature of each electrical sparks is expected near about 15,000° to

*Corresponding author's ORCID ID: 0000-0000-0000-0000
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21,000° Fahrenheit. This process help in many applications like in aerospace, nuclear and automotive industries, to machine accuracy and improper shapes in the different electrically conductive materials. These characteristics make Wire EDM is a process which remained as a competitive and economic machining option fulfills the demands of machining requirements of the short product development cycles.

Working Principle

WEDM works on the principle of utilizing the erosive effect of the dominated electric spark discharges on the electrodes. So this is a thermal erosion process. Sparks are generated in a dielectric liquid normally water or oil, between the electrode and the workpiece. The electrode can be taken as cutting tool. There is no physical connection between the two during the total process. Because erosion is engendered by electrical discharges, workpiece and electrode have to be electrically conductive. The machining procedure consists of stepwise removal small amounts of workpiece material melt or vaporized during the discharges. The volume removed by a single discharge is less, in the range of 106-104 mm3, but this process is usually repeated 10'000 times per second. Figure 1.2(a-d) provide a detailed explanation of the erosion process due to a single EDM discharge.

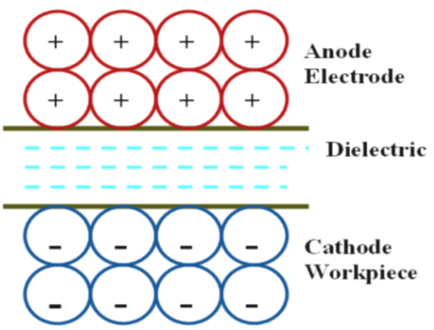


Fig 2: Pre-breakdown-Voltage applied between electrode and workpiece

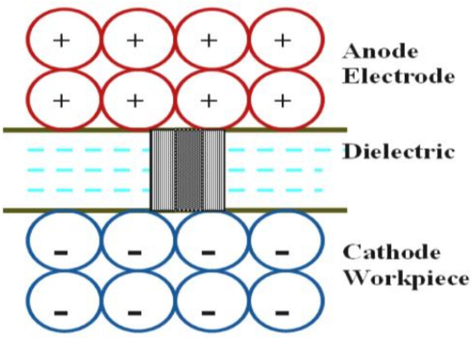


Fig 3: Breakdown-Dielectric breakdown, creation of the plasma channel

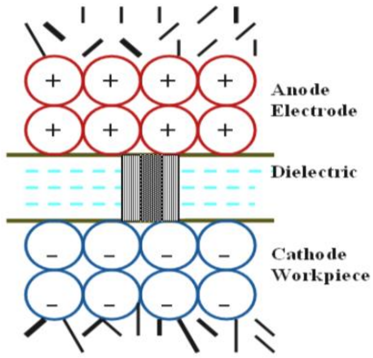


Fig 4: Discharge-Heating, melting and vaporizing of the workpiece material

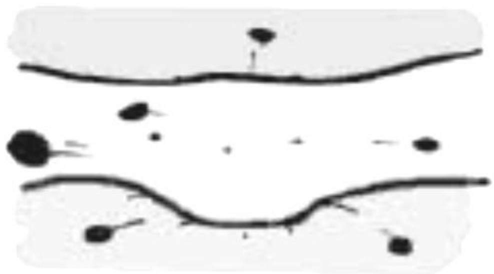


Fig 5: Post-discharge-Solidifying and flushing of the eroded particles by the dielectric

First voltage is applied between the workpiece and electrode. The ignition voltage is approximately 200V. The breakdown of the dielectric is performed by moving the electrode towards the workpiece. This would increase the electric field in the gap, until it is reached to the required point for breakdown. The location of the breakdown is between the proximate points of the electrode and the workpiece, but it also based upon the particles existing in the space. When the breakdown occurs, the voltage reduces and current increases at the same time. The bearing of stream is possible at this step, because the ionization of dielectric has happened and a channel of plasma has been engendered between the electrodes. In the next stage the discharge current is maintained constant, ascertaining the perpetual attack of ions and electrons in the electrodes. This will result in strong heating of the workpiece material, expeditiously engendering a minute bath of molten metal pool on the surface. Small amount of metal can directly vaporized because of heating. This will result in strong heating of the workpiece material, expeditiously engendering a minute bath of molten metal pool on the surface. Small amount of metal can directly vaporized because of heating. As it is a shock the plasma channel expands. So the radius of molten metal pool increased with the time. The distance between the workpiece and electrode during the process of discharge is a critical parameter. It is estimated that about 10 to 100 µm. In the final examination stage of the discharge, current and potential differences are turned off. On the examination of event it conducts the suction of the molten metal pool into the dielectric and leaves a minute crater on the surface of workpiece.

Process Parameters of WEDM

Production of a product in the desired shape and size with the desired characteristics and properties depends upon the selection of operating parameters of manufacturing processes Wire EDM process is a machining process controlled by a number of process parameters that can be changed or kept constant in a range. Slight difference in these parameters affects the performance of machining. So, that is a big requirement for the proper selection of the process parameters. Some of these process parameters which can be changed according to the demand are:

1) Pulse on Time or Pulse duration (Ton)
2) Pulse off Time or Pulse interval (Toff)
3) Peak Current (Ip)
4) Servo Voltage (Sv)
5) Wire Feed (Wf)
6) Wire Tension (Wt)
7) Water Pressure (Wp) or Flushing Pressure (Fp)

Literature

2015[3]: T. Muthuramalingam *et al*. Studied about the review of the contribution of electrical process parameters for efficient EDM process in different aspects such as state of art, modeling of EDM process parameters, influence of the discharge energy, , pulse genera-tors, pulse shape, monitoring the parameters and optimization of EDM process parameters. The following conclusions are made:

1) It has been found that the peak current and pulse duration are affected the performance measures in the EDM process.
2) It has been found that only less attention has been given for improving the electrical process parameters in EDM process in terms of pulse modification, monitoring and. adaptive controlling of process parameters

2014[6]: Ms. Shalaka Kulkarni *et al*. Studied to determining the optimum settings of the process parameters for single as well as multi response optimization during EDM of high carbon high chromium steel on the basis of taguchi method and utility concept. The L25 OA was used for experimental design. In the first stage (single response) best settings of process parameters were obtained one by one to obtain optimum values for MRR, SR and KW. It is found that TON is the most important factor for both KW and MRR, while TOFF has less significant effect on SR. In second stage (multi response) response table establishes the combination of higher levels of pulse on time, pulse off time, wire feed and lower flush and lower level of wire tension and upper flush is essential for obtaining optimal value of multiple performances for the predefined weightages

2014[2]: Ashok Kumar Choudhary *et al*. studied on material removal rate kerf width, surface roughness, gap current, and the kerf width. The experiments were performed under different parameter setting. Minitab software is used for analyze L_{27} orthogonal array experimental data. Following conclusion is obtained after analysis.

1) The Kerf width increases with increasing of pulse on time and peak current and decrease with the increase of pulse off time.
2) The surface roughness increases with increasing of pulse on time and peak current and decrease with the increase of pulse off time and spark gap voltage.

When the increase of pulse on time and peak current the material removal rate increase and MRR decrease with the increase of pulse off time, spark gap voltage and wire feed rate

2013[4]: M. Durairaja *et al*. studied on the cutting parameters in wire Edm for SS-304. The purpose of optimization is to obtain the best surface quality and minimum kerf width. In this study stainless steel 304 is used as a workpiece, brass wire of 0.25mm diameter used as a tool. The following conclusions are made.

1) Based on the taguchi optimization method, the best combination for input parameter get the minimum kerf width are 50v gap voltage, 2mm/min wire feed, 4 µs Pulse on time, 6 µs pulse off time and to get the minimum Surface roughness are 2mm/min wire feed, 40v gap voltage, 10 µs pulse off time 6µs pulse on time.
2) Based on the grey relational analysis, the best combinations for input parameter are 50v gap voltage, 2mm/min wire feed, 4 µs pulse on time and 4 µs pulse off time.

2012: Kode Jaya Prakash *et al*. [20] they concluded that wires with greater tensile strength can be produced but they faced adverse effects in terms of increase in resistance to breakage. Coated wires may work better in the present situation when surface finish and tool life is most preferred. The zinc coated brass wires works better when compared to simple brass wire because of its low rate of wear and low breakage at increased currents. Due to high accuracy and good quality of surface finish, WEDM is potentially an important process. The research is on for the development of the WEDM as Micro WEDM, where it can be used for the production of micro components, more efficiently and more effectively on industrial scale.

2011[2]: F. Klocke *et al*. studied on the Titanium alloys such as Ti6Al4V are frequently used in turbine industry components due to their excellent mechanical properties. These properties make it tough to machine with formal processes like that broaching, milling or grinding. The main conclusion of this paper is that eroded surfaces are visually better to inspect than ground surfaces. The non-destructive inspections of the sample allowed the estimation, that the ground specimens have an increased fatigue life. In addition to the main conclusion about the surface integrity analysis it can be emphasized that the process instabilities, which occur during Wire EDM of Ti6Al4V can directly be seen on the surface as black marks. The need for complex destructive inspection is not necessary. Process of unreliability which impacts the failure criteria of a WEDM part can easily be found by visual inspection. This provides the operator an opportunity to tune his process for a better and safer.

2008[1]: Jaharah A.G. *et al*. studied about the performance of the copper electrode when EDM used AISI H13 tool steel. The various parameters considered are the peak current, pulse off-time and pulse on-time. The effect of peak current settings (1, 2 and 4 A), pulse off time (1, 2 and 4 µs) and pulse on time (3, 6 and 12 µs) are investigated on the machining performance of the surface roughness (Ra), electrode wear rate (EWR) and material removal rate (MRR). Following conclusion made base on the result:

1) The optimal condition for the surface roughness was observed at low peak current, low pulse-on and pulse-off time.
2) High MRR is obtained when setting at high peak current, medium pulse-on time, and low pulse-off time. Therefore the peak current is observed the major factor affected the MRR and surface finish for the finishing and roughing operations.

2006: Ramakrishna *et al*. have proposed a multi objective optimization method in WEDM process by using parametric design of Taguchi method. The effect of various machining parameters such as delay time, pulse on time, wire tension, wire feed rate, and ignition current intensity has been studied through machining of heat-treated tool steel. It is found that the pulse on time and ignition current intensity have affected more than other parameters taken in this study.

Experimental Details

Work material: The material used for the experimentation purpose is EN-42. It is an air hardened cold work steel. It gives high level of hardness after the heat treatment with best dimensional stability. It provide good toughness with the medium wear resistance and is comparatively easy to machine. The EN-42 steel plate of 104mm x 97mm x 18mm size is mounted on WEDM machine tool and specimens of 5mmx5mmx18mm size are cut.

Methodology Used

The purpose of experimentation is to study the different changes of WEDM control factors on performance measures that are cutting rate and surface roughness. Also, it is planned to determine the range of different parameters required for the experimental design methodology used in this work. The response variables for this experimentation have been selected as cutting rate and surface roughness. The aim of these experiments is to examine the variations of WEDM control factors on the response variables that are cutting rate and surface roughness. Also, it is projected to figure out the range of different parameters important for the experimental design methodology used in this work. The experiments were complete on ELECTRONICA make SPRINTCUT 734 WEDM machine.

Table 1 Range of control factors for SPRINTCUT 734 WEDM machine

Sr. No.	Control Factor	Unit	Range	Mid Value
1	Pulse on time	µs	101 – 131	116
2	Pulse off time	µs	1 – 63	32
3	Peak current	A	10 – 230	120
4	Servo voltage	V	1 – 99	50
5	Wire feed	m/min	1 – 15	8
6	Wire tension	Kg	1 – 15	8

Table 2 Optimal ranges of significant control factors

Real Factor	Coded Factor	Parameter Name	Unit	Lower Limit	Upper Limit
Ton	A	Pulse on time	µs	105	120
Toff	B	Pulse off time	µs	30	45
Ip	C	Peak current	A	70	130
Wf	D	Wire feed	m/min	6	9

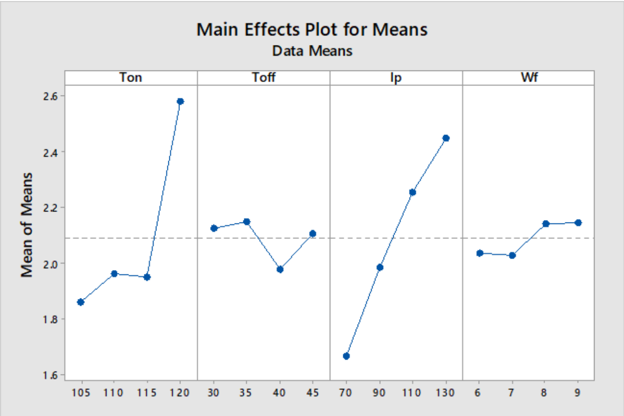
Result and discussion

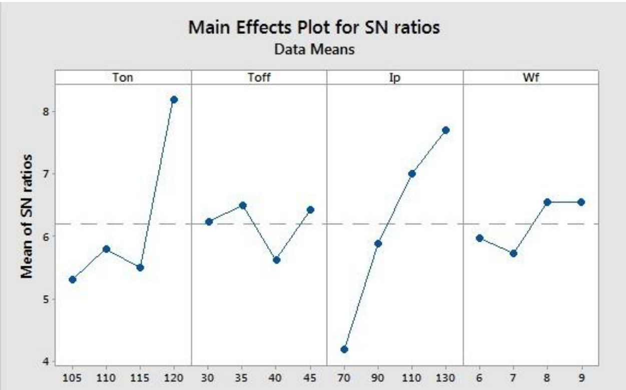
Effect of process parameters on surface roughness

The results of the experimentation regarding Surface roughness steel grade EN-42 have been discussed. From Minitab software L_{16} orthogonal array is selected and accordingly S/N ratios and Means for responses is calculated. Surface roughness analysis done here is depends on variables on four factors:

1) Pulse on time (µs)
2) Pulse off time (µs)
3) Peak current (Ip)
4) Wire feed (m/min)

Various graphs and tests have been constructed to determine which factors have a statistically significant effect on the surface roughness. Analysis of variance for S/N ratios and means for surface roughness contents calculated from software. The average surface roughness obtained from the surface roughness test conducted on 16 specimens. The surface roughness ranges from 1.21µm to 2.95µm.





Main effects plot for SN ratios

The effect of each parameter on surface roughness is plotted on the graph in form of lines from the figure. Main effects plot for S/N ratios it can be clearly seen that the surface roughness increases as the pulse on time is increased from 105µs to 110µs,but after that surface roughness decreases when pulse on time increases from 110µs to 115µs. The surface roughness value increase high when the pulse on time is increase from 115µs to 120µs. Main effects plot for S/N ratios between surface roughness and the pulse off time show that the surface roughness value increases when pulse off time increases from 30µs to 35µs, but after that surface roughness value decrease when pulse off time increases from 35µs to 40µs. The value of surface roughness increase as the value of pulse off time increase from 40µs to 45µs. Main effects plot for S/N ratios between surface roughness and peak current show that the surface roughness value increases continuously when peak current increases from 70Ato 130A. Main effects plot for S/N ratios between surface roughness and the wire feed show that surface roughness decrease when the wire feed increase from 6 m/min to 7 m/min but after that surface roughness value increase when wire feed increase from 7 m/min to 8 m/min, and it remain constant from 8m/min to 9m/min.

From this we can easily conclude that the pulse on time and peak current have the most significant effect on the surface roughness

Analysis of variance for SN ratio

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ton (µs)	3	21.906	21.906	7.3020	6.11	0.086
Toff (µs)	3	1.917	1.917	0.6390	0.53	0.660
Ip(A)	3	28.449	28.449	9.4998	7.96	0.061
Wf (m/min)	3	2.133	2.133	0.7112	0.60	0.690
Residual Error	3	3.585	3.585	1.1951		
Total	15	58.041				

Conclusion

Optimal combination for surface roughness

Physical	Optimal combination			
Requirement	Ton (µs)	Toff (µs)	Ip (A)	Wf (m/min)
Maximum Surface roughness	115	40	70	7
	Level 3	Level 2	Level 1	Level 2

1. It is concluded that for the surface roughness the minimum factor Ton (µs) has to be kept at level 3,Ip(A) has to be kept at level 2, and Toff (µs) has to be kept at the level1and Wf (m/min) has to be kept at the level 2.
2. According to ANOVA, for surface roughness the values of the percentage of contribution of process parameters are calculated for surface roughness. According to value of percentage of contribution of each variables for surface roughness the rank of variables in descending order are peak current (1) > pulse on time (2) > pulse off time > (3) wire feed (4)

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