International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 1697-1705 www.ijaem.net ISSN: 2395-5252

Study of Behavior of Process Performance Parameters of Wire Electric Discharge Machining (W-EDM)

Rupesh Singh[1], Ashutosh Dwivedi[2], Avinash Namdev[3], Sagar Singh Parihar [4]
[1]M.Tech Scholar,
[2, 3, 4]Assistant Professor
Department of Mechanical Engineering, Vindhya Institute of Technology and Science, Satna

Submitted: 05-06-2022 Revised: 17-06-2022 Accepted: 20-06-2022

ABSTRACT
Now a day, Wire Electrical Discharge Machining is used vastly where the conventional machining process shows their limitations. This Machining is used to manufacture geometrically intricate and complex shapes with higher accuracy and better surface finish with higher material removal rate. In the present study, the performance parameters i.e. cutting speed and surface roughness were investigated. The experiments were conducted under the various cutting parameters of TON, TOFF, Tension, Flushing rate at constant Wire Feed of 10 mm/sec. In the present study, molybdenum wire having diameter 0.25mm was used as wire electrode. The molybdenum wire was operated on the Skd 61 alloy steel plate work piece material having thickness of 20 mm. During the experimentation, it had been found that the cutting speed and surface roughness increases with increase in peak current and tension while decreases with the increase in flushing rate.
KEYWORDS: WEDM, PROCESS PARAMETERS, SKD61, SURFACE ROUGHNESS

I. INTRODUCTION

Additional the development of mechanical industry, the demands for alloy materials having high hardness, toughness and impact resistance are increasing. However, such materials are difficult to be machined by traditional machining methods. Hence, non-traditional machining methods including electrochemical machining, ultrasonic machining, electrical discharging machine (EDM) etc. are applied to machine such difficult to machine materials. WEDM process with a thin wire as an electrode transforms electrical energy to thermal energy for cutting materials. With this process, alloy steel, conductive ceramics and aerospace materials can be machined irrespective to their hardness and toughness. Furthermore, WEDM is capable of producing a fine, precise, corrosion and wear resistant surface (1).

WEDM is considered as a unique adoption of the conventional EDM process, which uses an electrode to initialize the sparking process. However, WEDM utilizes a continuously travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05-0.30 mm, which is capable of achieving very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining.

1.1 IMPORTANCE OF WEDM PROCESS IN PRESENT DAY MANUFACTURING

Wire electrical discharge machining (WEDM) technology has grown tremendously since it was first applied more than 30 years ago. Its broad capabilities have allowed it to encompass the production, aerospace and automotive industries and virtually all areas of conductive material machining. This is because WEDM provides the best alternative or sometimes the only alternative for machining conductive, exotic, high strength and temperature resistive materials, conductive engineering ceramics with the scope of generating intricate shapes and profiles (1).

WEDM has tremendous potential in its applicability in the present day metal cutting industry for achieving a considerable dimensional accuracy, surface finish and contour generation features of products or parts. In addition, the cost of wire contributes only 10% of operating cost of WEDM process. The difficulties encountered in the die sinking EDM are avoided by WEDM, because complex design tool is replaced by moving conductive wire and relative movement of wire guides.

1.2 STATEMENT OF THE PROBLEM

The present work "On the Process Performance of Wire Electric Discharge Machining (W-EDM)" has been undertaken keeping into consideration the following problems:

- It has been long recognized that cutting conditions such as pulse on time, pulse off time, open voltage, feed rate override, wire feed, servo voltage, wire tension and flushing pressure machining parameters should be selected to optimize the economics of machining operations as assessed by productivity, total manufacturing cost per component or other suitable criterion (2).
- High cost of numerically controlled machine tools, compared to their conventional counterparts, has forced us to operate these machines as efficiently as possible in order to obtain the required payback.
- New materials of increasing strengths and capabilities are being developed continuously and response characteristics are not only dependent on the machining parameters but also on materials of the work part (3). Skd 61, die steel is one such material which can be used in applications of extreme loads such as hot-work forging, extrusion, manufacturing punching tools, mandrels, mechanical press forging die, plastic mould and die-casting dies, aircraft landing gears, helicopter rotor blades and shafts, etc. The investigation of optimal machining parameters for Skd 61 is thus very essential.
- Predicted optimal solutions may not be achieved practically using optimal setting of machining parameters suggested by any optimization technique. So, all the predicted optimal solutions should be verified experimentally using suggested combination of machining parameters.

1.3 OBJECTIVES OF THE PRESENT INVESTIGATION

Experimental determination of the effects of the various process parameters viz pulse on time, pulse off time, open voltage, feed rate override, wire feed, servo voltage, wire tension and flushing pressure on the performance measures like cutting speed and surface roughness in WEDM process.

1. Optimization of the performance measures using Genetic algorithm.
2. Validation of the results by conducting confirmation experiments.
3. Modeling of the performance measure using response surface methodology.

II. LITERATURE REVIEW

Several researchers have attempted to improve the performance characteristics namely the surface roughness, cutting speed, dimensional accuracy and material removal rate etc.

Puri and Bhattacharyya (4) employed Taguchi methodology involving alloy (Ti-6Al-4V) and used a data-mining technique to study the effect of various input parameters of WEDM process on the cutting speed and SR. They reformulated the WEDM domain as a classification problem to identify the important decision parameters. In their approach, however, the optimal process parameters for the multiple responses need to be decided by the engineers based on judgment.

Puri and Bhattacharyya (5) investigated the wire lag phenomenon in wire-cut electrical discharge machining process and the trend of variation of the geometrical inaccuracy caused due to wire lag with various control parameters. They found that the optimal parametric settings with respect to productivity, SR and geometrical inaccuracy due to wire lag were different.

Tosun et. al. (6) investigated the effect and optimization of machining parameters on the kerf (cutting width) thirteen control factors with three levels for an orthogonal array L27 (313) to find out the main parameters that affect the different machining criteria, such as average cutting speed, surface roughness values and the geometrical inaccuracy caused due to wire lag.

Huang and Liao (7) presented the use of grey relational and S/N ratio analysis, for determining the optimal parameters setting of WEDM process. The results showed that the MRR and surface roughness are easily influenced by the table feed rate and pulse on time.

Kuriakose et. al. (8) carried out experiments with titanium and material removal rate (MRR) in wire electrical discharge machining (WEDM) operations. Based on ANOVA method,

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 1697-1705 www.ijaem.net ISSN: 2395-5252

the highly effective parameters on both the kerf and the MRR were found as open circuit voltage and pulse duration, whereas wire speed and dielectric flushing pressure were less effective factors. The results showed that open circuit voltage was about three times more important than the pulse duration for controlling the kerf, whereas open circuit voltage for controlling the MRR was about six times more important than pulse duration.

Yan et. al. (9) performed experiments on a FANUC W1 CNC wire electrical discharge machine for cutting both the 10 and 20 vol. % Al2O3 particles reinforced 6061Al alloys-based composite and 6061Al matrix material itself. Results indicated that the cutting speed (material removal rate), the surface roughness and the width of the slit of cutting test material significantly depend on volume fraction of reinforcement (Al2O3 particles).

Manna and Bhattacharyya (10) performed experiments using a typical four-axes Electronica Supercut-734 CNC-wire cut EDM machine on aluminium-reinforced silicon carbide metal matrix composite Al/SiCMMC. Open gap voltage and pulse on period are the most significant machining parameters, for controlling the metal removal rate. The open gap voltage affected the cutting speed significantly. Wire tension and wire feed rate were the most significant machining parameters, for the surface roughness. Wire tension and spark gap voltage setting were the most significant for controlling spark gap.

III. EXPERIMENTAL SET-UP AND PROCESS PARAMETER SELECTION

3.1 MACHINE TOOL

Experiments have been performed on CNC Wire cut EDM (Fanuc robocut α-1iE) at Central Workshop of Vindhya Institute of Technology and Sciences Satna. (India). The WEDM machine tool (Figure 3.1) has the following specifications:

MACHINE MAIN UNIT

Type - Submerge Machining / Flushing Machining having following parameters

Maximum dimension of work piece -	Standard - 1050 X 820 X 300 Optional - 1050 X 820 X 400
Maximum work piece weight	1000 kg
Table stroke	600 x 400 mm
Z – axis stroke	310 mm
U – axis & V-axis	± 100 mm x ± 100 mm
Driving motor x/ y axis	Fanuc AC servo motor α 2/5000 i
Maximum table feed rate	900 mm / min
Wire diameter	φ 0.1 to φ 0.3
Wire tension	250 to 2500
Wire feed rate	1 to 15 m /min
Wire guide	Die Guide
Maximum wire weight	16 kg

DIELECTRIC FLUID UNIT

Dielectric fluid	Demineralised water
Tank capacity	800 litre
Filtration precision	1 to 3 µm
Ion exchange resin	10 L x 1 standard
Dielectric fluid resistivity control	5 to 20 x104 Ω cm
External dimension	1000 x 1750 x 1600 mm

NUMERICAL CONTROL UNIT

Controlled axis	X , Y , Z , U, V
Least input increment	0.0001 mm
Least command increment	0.0001 mm
Interpolation	Linear, Circular
Maximum programmable dimension	± 99999.99999 mm
Position command	Relative and Absolute
NC Programme storage	4 Mb
Feed rate	Rapid 900 mm/min
Cutting feed rate	0.0001 to 50 mm/min
Manual	100 , 200, or 300 mm/min

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 1697-1705 www.ijaem.net ISSN: 2395-5252

3.2 WORK PIECE MATERIAL

The Skd 61 alloy steel plate of 100mm x 50mm x 7.5mm size has been used as a work piece material for the present experiments. Skd 61 is special hot-worked chromium tool-steel with good hardness and toughness properties. It is used for extreme load conditions such as hot-work forging, extrusion etc. It has varied practical applications such as manufacturing of punching tools, mandrels, mechanical press forging die, plastic mould and die-casting dies, aircraft landing gears, helicopter rotor blades and shafts. The working life and dimensional accuracy of Skd 61 alloy steel dies and tools can be improved with suitable heat treatment.

Table 3.1 Chemical composition of Skd 61 alloy steel

Material	C	Si	Mn	P	S	Cr	Mo	Cu	V
Skd 61	0	1	0	0	0	5	1	0	1

3.3 PREPARATION OF SPECIMENS

The Skd 61 alloy steel plate of 100mm x 50mm x 7.5mm size is mounted on the FANUC robocut α-1iE WEDM machine tool (Figure 3.1) and specimens of 10mmx2mmx7.5mm size are cut. Work piece specimen are shown in Figure 3.3.

Figure 3.2 Work piece on the work table

Figure 3.3 work piece material specimen

3.4 MEASUREMENT OF EXPERIMENTAL PARAMETERS

The discussions related to the measurement of WEDM experimental parameters e.g. cutting speed, material removal rate and surface roughness are presented in the following subsections.

3.4.1 Cutting speed

For WEDM, cutting speed is a desirable characteristic and it should be as high as possible to give least machine cycle time leading to increased productivity. In the present study cutting speed is a measure of job cutting which is digitally displayed on the screen of the machine and is given quantitatively in mm/min.

3.4.2 Material removal rate

The mean cutting speed data (Cs) was observed directly from the computer monitor, which was attached to the machine tool. Generally, during this process the wire diameter is kept constant.
Therefore, the width of cut (W) remains constant. Therefore, the MRR for the WEDM operation is calculated using Eq. 3.1 which is shown below:

$$MRR = Cs \times L \quad (3.1)$$

Where
Cs = cutting speed in mm/mint.
L = thickness of the material in mm.

3.4.3 Surface Roughness

Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. Roughness is a

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 1697-1705 www.ijaem.net ISSN: 2395-5252

measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if small, the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface.

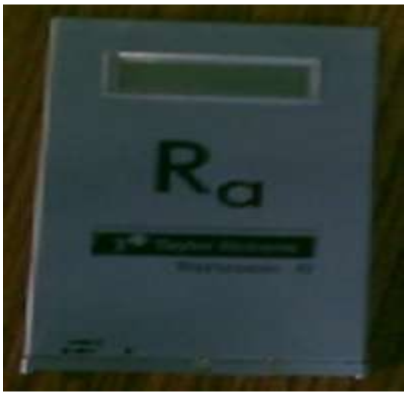


Figure 3.4 surface roughness measurement set up

The parameter mostly used for general surface roughness is Ra. It measures average roughness by comparing all the peaks and valleys to the mean line, and then averaging them all over the entire cut-off length. Cut-off length is the length that the stylus is 27 dragged across the surface; a longer cut-off length will give a more average value, and a shorter cut-off length might give a less accurate result over a shorter stretch of surface.

IV. EXPERIMENTATION

The experiments were accomplished on the WEDM machine. Following steps were followed in the cutting operation:

1. The wire was made vertical with the help of verticality block.
2. The work piece was mounted and clamped on the work table.
3. A reference point on the work piece was set for setting work co-ordinate system (WCS). The programming was done with the reference to the WCS. The reference point was defined by the ground edges of the work piece.
4. The program was made for cutting operation of the work piece and a profile of 10 mm x 2 mm x 7.5 rectangular was cut.

4.1 SELECTION OF PROCESS PARAMETERS

In order to identify the process parameters that may affect the machining characteristics of WEDM machined parts is shown in Figure 4.1

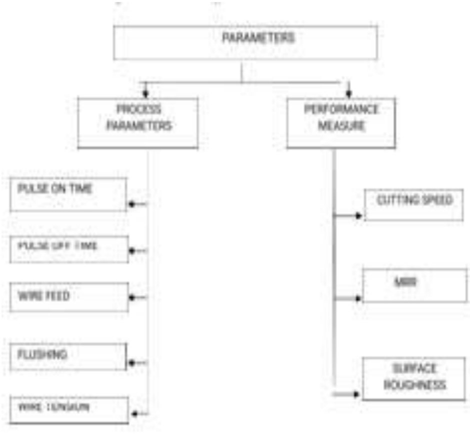


Figure 4.1 Parameters flow diagram

V. RESULT AND DISCUSSIONS

Table 6.1 shows the result obtained by machining on WEDM for various values of TON, TOFF, Tension, Flushing Rate to get different values of Cutting and Surface Roughness.

Table 5.1 Machining results obtain on WEDM by Experimentation

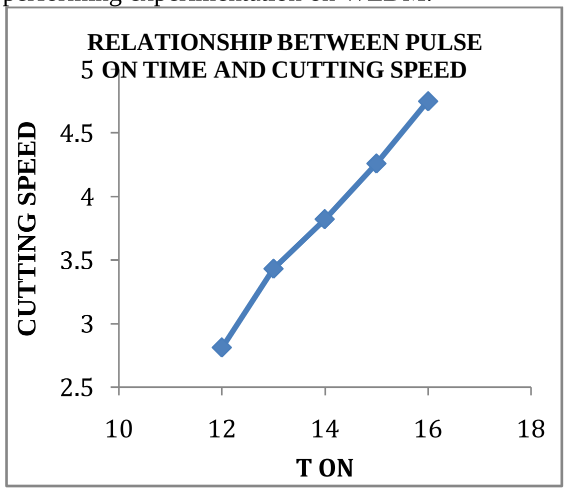
S NO	T ON	T OFF	TENSION	FLUSHING RATE	CUTTING RATE	SURFACE ROUGHNESS
1	11	50	1700	10	2.4091	5.1
2	11	60	1700	10	2.3441	5
3	11	70	1700	10	2.1003	4.9
4	11	80	1700	10	1.9311	4.8
5	11	90	1700	10	1.8782	4.7
6	11	100	1700	10	1.6721	4.6
7	11	110	1700	10	1.2101	4.5
8	12	50	1700	10	2.7757	4.7
9	13	50	1700	10	3.4346	4.8
10	14	50	1700	10	3.8275	4.9
11	15	50	1700	10	4.2658	5.1
12	16	50	1700	10	4.7543	5.3
13	9	50	1700	10	0.4197	4.5

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 1697-1705 www.ijaem.net ISSN: 2395-5252

14	10	50	1700	10	1.522 8	4.6
15	11	50	1700	12	2.584 2	5
16	12	50	1700	14	2.705 4	4.8
17	12	50	1700	16	2.597 8	4.5
18	12	50	1700	11	2.932	5.1
19	12	50	1700	13	2.811 2	4.9
20	12	50	1700	15	2.630 5	4.7
21	12	50	1750	10	2.800 2	4.3
22	12	50	1800	10	2.822 7	4.4
23	12	50	1850	10	2.861 3	4.7
24	12	50	1900	10	2.902 1	4.9
25	12	50	1950	10	2.260 1	5.1
26	12	50	1600	10	2.730 8	4.2
27	12	50	1650	10	2.569 8	4.3
28	12	50	1500	10	2.440 3	4.1
29	12	50	1400	10	2.265 2	4
30	12	50	1550	10	2.316 1	4.2

5.1 STUDYING THE BEHEVIOR OF INPUT PARAMETERS ON THE CUTTING SPEED

The Following Figures are obtained between the input parameters and the Cutting Speed after performing experimentation on WEDM.



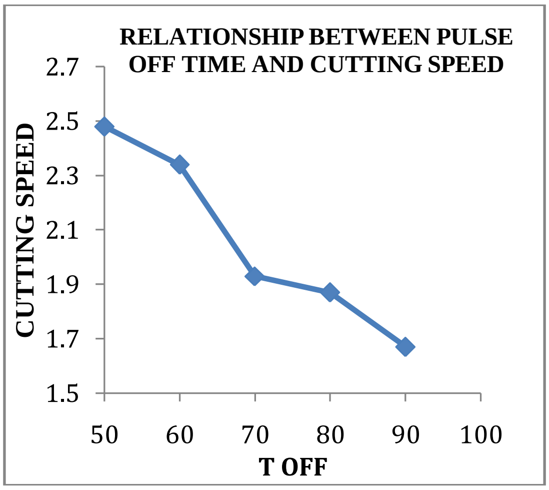
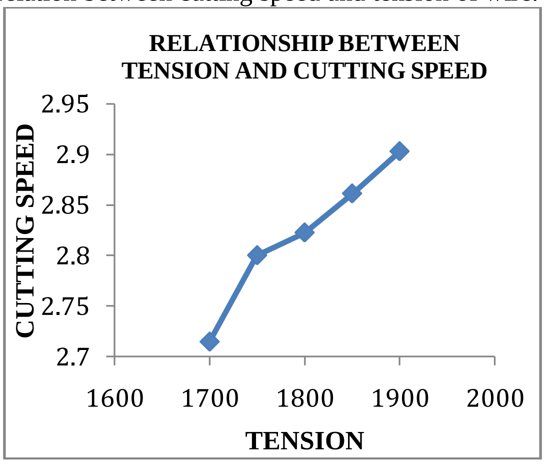


Fig 5.1 shows that cutting speed increases with increase of pulse on time. When pulse on time is increase the spark generation duration is more which results in more melting of material of the workpeice, hence the cutting speed increases. Fig 3.6 clearly shows that there is a direct relation between cutting speed and pulse on time.

Fig 5.2 shows that cutting speed decreases with increase of pulse off time. When pulse off time is increases the spark generation duration is less which results in less melting of the material of the workpeice. Hence the cutting speed decreases. Fig 3.7 clearly shows that there is inverse relation between cutting speed and pulse off time.

Fig 5.3 shows that cutting speed increases with increase in the tension of wire. When the tension is increases the wire remains straighter hence the gap between the workpeice and wire is proper which results in more stable spark and better melting of the material. Hence the cutting speed increases. Fig 6.3 clearly shows that there is direct relation between cutting speed and tension of wire.



International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 1697-1705 www.ijaem.net ISSN: 2395-5252

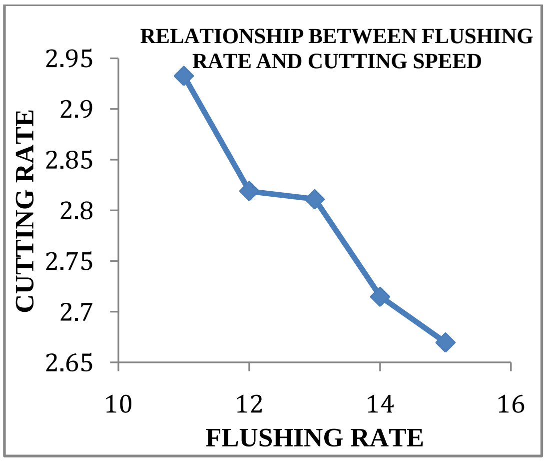
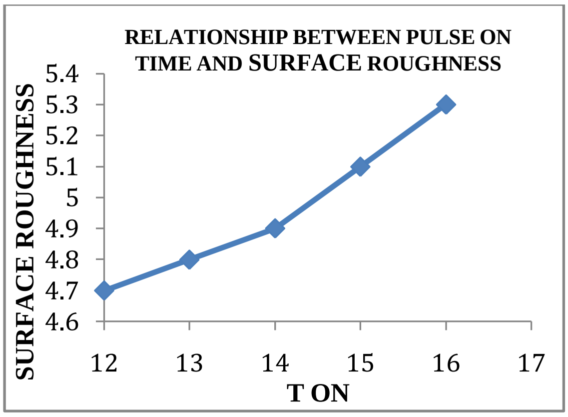


Fig 5.4 shows that cutting speed decreases with increase in the flushing rate of the dielectric fluid. When the flushing rate is increases the spark generation becomes unstable which results in less removal of material due to less melting of there workpeice. Fig.5.4 clearly that there is inverse relation between cutting speed and flushing rate.

5.2 STUDYING THE BEHAVIOUR OF INPUT PARAMETERS ON THE SURFACE ROUGHNESS

The Following behavior plots are obtained between the input parameters and the Surface Roughness after performing experimentation on WEDM.



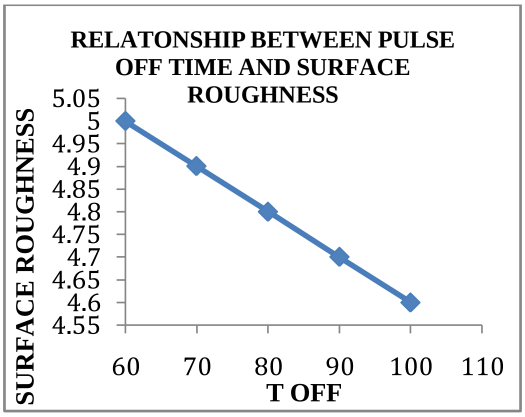
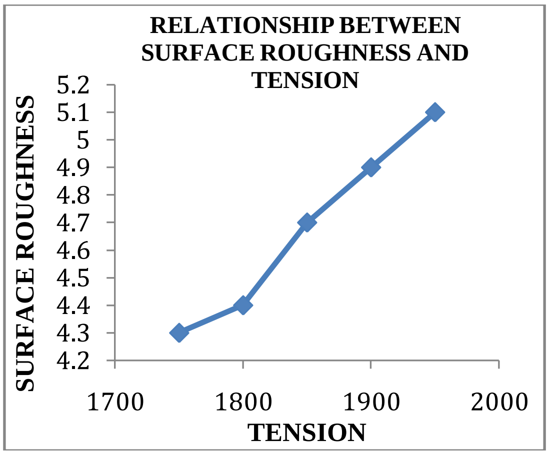


Fig 5.5 shows that surface roughness increases with increase in the pulse on time. When the pulse on time increases the spark generation increases which result in more material removal of the workpiece which forms larger crater on surface of the workpiece which leads to poorer surface finish.

Fig 5.6 shows that surface roughness decreases with increase in the pulse off time. When the pulse off time increase the spark generation decreases which results in less material removal of the workpiece which forms smaller crater on the surface of the workpeice which leads to better surface finish.



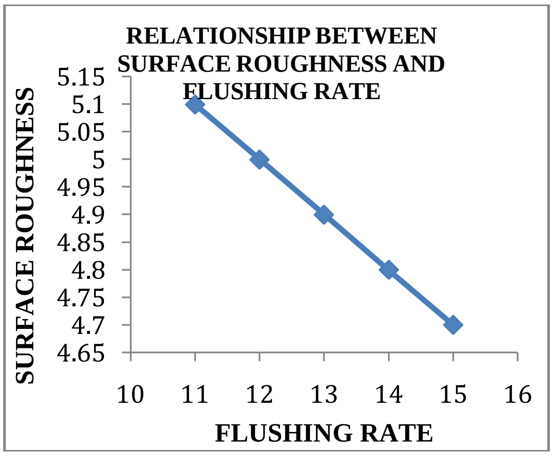


Fig 5.7 shows that surface roughness increases with increase in the tension of wire. When the tension is increases the spark generation is more stable hence the material removal of workpeice increases which forms larger crater on the surface of the workpeice which leads to poorer surface finish.

Fig 5.8 shows that surface roughness decreases with increase in the flushing rate of dielectric fluid. When the flushing rate increases the spark generation is less stable hence the material of workpeice decreases which forms smaller crater on surface of the workpeice which leads to better surface finish.

VI. CONCLUSION

The experiments were conducted under the various cutting parameters of TON, TOFF, Tension, Flushing rate at constant Wire Feed of 10 mm/sec. In the present study, molybdenum wire having diameter 0.25mm was used as wire electrode. The molybdenum wire was operated on the Skd 61 alloy steel plate work piece material having thickness of 20 mm. During the experimentation, it had been found that the cutting speed and surface roughness increases with increase in peak current and tension while decreases with the increase in flushing rate.

REFERENCES

[1]. Mahapatra, Patnaik (2007), Optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method, International Journal of Advanced Manufacturing Technology, 34, 911-925

[2]. Maneesh. Yadav, Shailesh, Pandey, Sumit Chaudhary, Qasim Murtaza (2012) , Effects of Machining Variables on Surface Roughness in Wire-EDM of AISI D3, International Journal of Engineering Sciences, Vol. 01, Issue 03, September 2012

[3]. N. Lusi et al., "Multiple Performance Optimization in the Wire EDM Process of SKD61 Tool Steel Using Taguchi Grey Relational Analysis and Fuzzy Logic", Applied Mechanics and Materials, Vol. 493, pp. 523-528, 2014

[4]. Puri and Bhattacharyya B. 2003 “An analysis and optimization of the geometrical inaccuracy due to wire lag phenomenon in WEDM”, International journal of machine tool and manufactures ,43,151-159

[5]. Puri and Bhattacharyya “Simultaneous optimization of multiple quality characteristics of wedm based on fuzzy logic and taguchi techniques”,proceedings of fifth asia pacific industrial engineering and management system conference.

[6]. Tosun et. al. ,”an investigation on wire wear in WEDM’’ ,Journal Of Material Processing Technology ,134(3),273-278 2003.

[7]. Liao, Y.S., Huang, J.T. and Su, H.C., "A Study on the Machining Parameters Optimization of the Wire Electrical Discharge Machining", Journal of Materials Processing Technology, 71, pp. 487-493, 1997.

[8]. Kuriakose, S., & Shunmugam, M. S. (2004). Characteristics of wire-electro discharge machined Ti6Al4V surface. Materials Letters, 58(17), 2231-2237.

[9]. Yan, Tsai, Huang, Long, Chorng (2005), Examination of wire electrical discharge machining of Al2O3p/6061Al composites, International Journal of Machine Tools & Manufacture, 45, 251–259.

[10]. Manna, Bhattacharyya, (2006), Taguchi and Gauss elimination method: A dual response approach for parametric optimization of CNC wire cut EDM of AlSiCMMC, International Journal of Advanced Manufacturing Technology, 28, 67–75.

[11]. Benedict, G.F. (1987), “Electrical discharge machining (EDM), nontraditional manufacturing process”, Marcel Dekker, Inc, New York & Basel, 231-232.

[12]. 12.Biing Hwa Yan, Hsien Chung Tsai and Fuang Yuan Huang(2005) The effect in EDM of a dielectric of a urea solution in water on modifying the surface of titanium,

International Journal of Machine Tools and Manufacture, 2005; 45: 194–200.
[13]. Bentley, S.A., Mantle, A.L., Aspin wall, D.K., (1995). The effect of machining on the fatigue strength of a gamma titanium aluminized inter metallic alloy, 1999; 7(8): 967–969.
[14]. Danial Ghodsiya (2012) Optimization Material Removal Rate in WEDM Titanium Alloy using the Taguchi Method. Research Journal of Applied Sciences, Engineering & Technology.2012 4(17):3154-3161.
[15]. GAO Qing(2008) Parameter optimization model in electrical discharge machining process, Journal of Zhejjan University Science A, 2008; 9(1): 101–108.
[16]. Gill Singh, Singh Jagdev (2010) and Effect of Deep Treatment on Mach inability of Titanium Alloy (Ti-6246) in EDM. Journal of Materials and Manufacturing Processing Technology, 25; 378-385, 2010.
[17]. Lin, J.L. and Tarng, Y.S., "Optimization of the Multi-Response Process by the Taguchi Method with Grey Relational Analysis ", The Journal of Grey System, 4, pp. 355-370, 1998.
[18]. P. J. Ross, "Taguchi Techniques for Quality Engineering ", McGraw-Hill, New York.
[19]. Deng, J.L., "Introduction to Grey System ", The Journal of Grey System, Vol.1, pp.1-24, 1989.
[20]. Hsia, K.H. and Wu, J.H., "A Study on the Data Preprocessing in Grey Relation Analysis", Journal of The Chinese Grey System Association, Vol.1, No.1, pp.47-53, 1998.