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Effect of Input Parameters on SR and MRR for Tool Steel AISI L2 By Electric Discharge Machine (EDM)

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K E Y W O R D S

Electrical discharge machining (EDM), Full Factorial, Material removal rate (MRR), Surface roughness(SR), X-ray diffraction

A B S T R A C T

Electric discharge machine (EDM) or may be call electric spark machine is one of the most important cutting process or manufacturing process because it gives high accurate dimension and can be produced the most complex shape. In this present material removal rate and surface roughness for tool steel AISI L2 studied. The input parametric for this process is current, pulse on time (T_{on}) and pulse off time (T_{off}).A full factorial method is used to formulate machine parameters and find the optimal process parameters of an electric spark. The result shows that the Surface roughness increasing with increasing current and pulse on time is increases while no effect by increase in pulse off time. Best surface roughness when using low current and pulse in time. The material removal rate is increasing with increasing in current and pulse on time while decreasing when pulse of time is increased. The experimented and predicted values by using Minilab17 software of this process are approximately equal.

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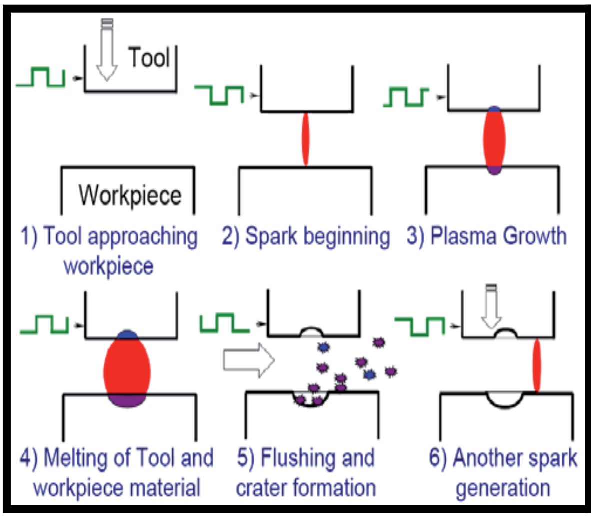
1. INTRODUCTION

Electric spark machine (EDM) is non-traditional, thermal electric machine. It's used in wide range number of industrial applications. EDM process is done without any contact between the workpiece and tool electrode so no mechanical stress is exerted ion the workpiece as shown in Figure. (1-a). Electric discharge machines can be classified into two types, die sinking EDM'ed and wire EDM [1].Wire-EDM applications almost like the cutting by electrical saw while in die-sinking the workpiece is taken the same shape in the tool electrode. EDM is a manufacturing method used to cut electrically conductive material only and also used to cutting hard material that was the most difficult cut in the traditional machine such as turning, milling, sawing and etc. [2]. Mechanism of material removal is done by converting electrical energy into thermal energy through a series of successive sparks between the workpiece and the tool electrode in a dielectric liquid the mechanism of plasma development as shown in Figure. (1-b) [3].



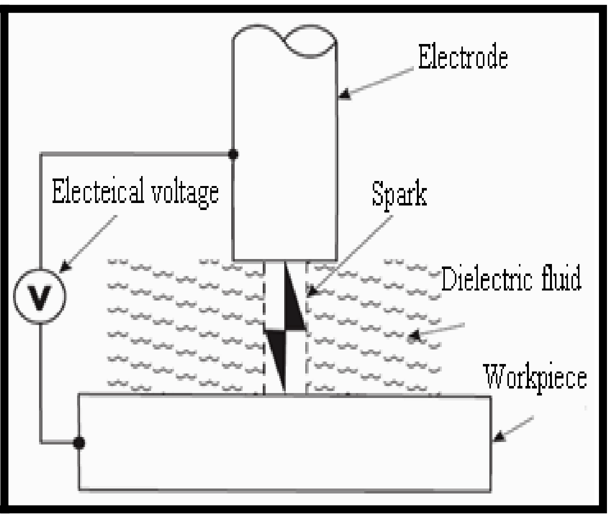


Figure1: a Spark initiation in EDM process [4]. **Figure 1:b** EDM Process Mechanism [5].

The performance of the EDM process is mainly affected by many electric parameters as far as current, polarity, Voltage, Pulse on time, Pulse off time, Electrode gap and also non electrical parameters such as workpiece and tool material, dielectric liquid pressure. All of these parameters (electrical and non-electrical) has a significant impact on the EDM'ed output response like surface roughness (SR), Metal removal rate (MRR) [6].Many research was done on this topic as B. Nahak and A. Srivastava said that MRR and surface roughness was increasing with rising in current and pulse on time in tool steel material [7]. Haneen L. Abdulwahhab also show that material removal rate and surface roughness increasing with rising current and pule on time at constant pulse off time [8]. Safa R. Fadhil found the best value of MRR and Ra was found by using Gr powder, whereas the best value of EWR was found by using Al_2O_3 powder also she seen MRR and SR increasing with any rise in the current [9]

2. ELECTRIC DISCHARGE MACHINE RESPONSE MESURMENT:

Surface roughness is a very important response to each cutting process. Electrical spark machining (EDM) process surface consisting of a large number of craters generated by discharge energy [10]. Many input parameters were influenced by the surface roughness of the EDM process such as Current, Voltage, Pulse on time, Tool electrode, Polarity and Workpiece materials, type of the dielectric fluid and even electrode dimensions. High parametric effected on surface roughness was current [11].

I. Surface roughness (SR) and material removal rate (MRR):

Surface roughness increasing when increasing MRR, MRR is a measurement of performance for the workpiece's corrosion rate which is usually used to measure the impact at which machining is carried out. The volumetric amount of workpiece material removed per unit time is expressed [12].

MRR was measured according to equation (1), which depends on the weight of the workpiece before and after machining, dividing to machining time [13].

$$MRR = \frac{\text{Wiw} - \text{Wfw}}{T * \rho} \quad \text{..... (1)}$$

MRR = Material Removal Rate (mm^3/min).

Wiw = Initial weight of workpiece (g).

Wfw = Final weight of workpiece (g).

ρ = Density (g/cm³) & T = Machining time (min)

3. EXPERIMINTAL PRODUCE

In this research pure copper is selected as a tool electrode and tool steel AISI L2 as a workpiece with dimension (32x27x10) mm for electrode and (30x20x3) mm for workpiece with cutting 10 mm from end of the sample as shown in Figure 2 . Chemical composition for workpiece and tool electrode as shown in Table I.

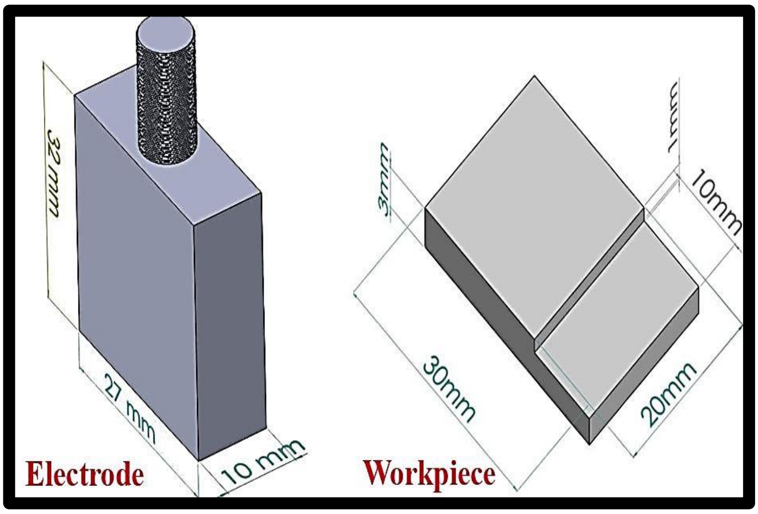


Figure 2: Electrode and workpiece shape and dimensions.

TABLE I: Chemical composition for workpiece and electrode.

Workpiece material		**Tool electrode**	
Element	**Weight (%)**	**Element**	**Weight (%)**
C	0. 690	Al	0.0023
Si	0.276	S	0.00006
Mn	0.406	Sn	0.0018
P	0.0091	P	0.0008
S	0.003	Fe	0.024
Mo	< 0.002	Mn	< 0.0004
Cr	0.585	Cr	0.0071
Ni	0.0305	Sb	0.0082
		Cu	99.9

The machine parameter can be into fixed parameters and changed parameters such as current, T_{on} and T_{off} as shown in Table II .

TABLE II: Machine parametric value in this study

Machining Parameters	Values
Current	10 ,20 ,30 A
T_{on}	50 , 100 , 150µs
T_{off}	6.5 , 12 ,25µs
Polarity	Positive
Dielectric fluid	Transformer oil
High voltage (H.V)	240 V 1.5 A
S code (S CODE)	20
Servo feed (SVO)	75 %
Working time (W.T)	0.6 sec
Jumping time (J.T)	0.8 mm
Gap code (GAP)	9
Depth of cut	1 mm

In Table II S code (SCODE) means that a name of file who saving inthe machining program , while gab code (GAP) is a constant number saving in machining program multiply number find on a frame of the machine to give a distance of gap between electrode and workpiece who generated cutting spark. Jumping time mean the distance who was the electrode jumping to save a constant gab between workpiece and electrode but in the program it calls was jumping time because machining time equal to working time add to jumping time so it replaced by a unit to distance. Experiments are done on a die-sinking EDM machine called CHMER of the model (CM.323C), which is placed at the center of the training and workshop in the University of Technology /Baghdad Figure 3.

Figure 3: Chemer EDM machine at UOT

4. RESULTS AND DISCUSSIONS

Experiment result and predict result for SR and MRR with machine parameter are shown in Table III. Design of experimental is done by using full factorial to give (all prospects) 27 numbers of experiments on program minilab17 software.

TABLE III: Experiment and predict value with machine parametric

No. Sample	Ip	T_{on}	T_{off}	Exp. SR (μm)	Pred.SR (μm)	Exp. MRR (mm^3/min)	Pred. MRR (mm^3/min)
1	10	50	6.5	3.736	4.24481	1.6151881	1.27887
2	10	50	12	4.646	4.35915	1.3291163	1.27887
3	10	50	25	4.570	4.32615	1.0885550	1.27887
4	10	100	6.5	4.573	4.67581	1.4983194	1.37780
5	10	100	12	4.560	4.67515	1.5308379	1.37780
6	10	100	25	4.533	4.63515	1.4389920	1.37780
7	10	150	6.5	4.916	4.99715	1.6453280	1.76209
8	10	150	12	4.226	4.11381	1.5784240	1.76209
9	10	150	25	4.280	4.01281	1.5315224	1.76209
10	20	50	6.5	4.630	4.35970	2.9842468	3.15462
11	20	50	12	4.463	4.47404	2.9337510	3.15462
12	20	50	25	4.603	4.44104	2.8141470	3.15462
13	20	100	6.5	4.756	4.79070	3.5288922	3.25355
14	20	100	12	4.753	4.79004	3.3021556	3.25355
15	20	100	25	4.740	4.75004	3.2228396	3.25355
16	20	150	6.5	5.173	5.11204	3.8235531	3.63784
17	20	150	12	4.143	4.22870	3.7692170	3.63784
18	20	150	25	3.813	4.12770	3.7592256	3.63784
19	30	50	6.5	6.226	5.98748	4.6493276	4.43252
20	30	50	12	5.826	6.10181	4.6651595	4.43252
21	30	50	25	5.663	6.06881	4.5185568	4.43252
22	30	100	6.5	6.556	6.41848	3.4574730	4.53145
23	30	100	12	6.570	6.41781	4.7083627	4.53145
24	30	100	25	6.490	6.37781	4.8005027	4.53145
25	30	150	6.5	6.760	6.73981	4.8324964	4.91574
26	30	150	12	5.830	5.85648	5.3053470	4.91574
27	30	150	25	5.803	5.75548	4.7019175	4.91574

These coefficients are used to develop the statistical model; the quantitative relationship between input parameters and MRR, SR are obtained in the equation of regression.

$MRR = - 0.764 + 0.2544\ Ip - 0.0085\ T_{on} + 0.0226\ T_{off} - 0.00299\ (Ip)^2 + 0.000057\ (T_{on})^2 - 0.00176\ (T_{off})^2 + 0.000047\ Ip * T_{on} + 0.00125\ Ip * T_{off} + 0.00007\ Ton * T_{off}$

$SR = 4.370 - 0.1995\ Ip + 0.0325\ T_{on} - 0.0139\ T_{off} + 0.00756\ (Ip)^2 - 0.000128\ (T_{on})^2 + 0.00228\ (T_{off})^2 + 0.000035\ Ip * T_{on} - 0.001339\ Ip * T_{off} - 0.000482\ Ton * T_{off}$

SR increasing with the increase in current because of the increasing the current led to increaseing the discharge energy and the impulsive force, material removal increases from the surface and generating deeper and larger discharge craters, these factors led to increasing the surface roughness. Also, SR decreases with decrease in pulse on time because when (T_{on}) is low that is led to a lower temperature for the surface machining thus producing more surface smoothness and volcanic crater are much small, while no change is occurred on SR when pulse off time is changes. Figure 3 Show the effect of current, pulse on time and pulse off time on SR.

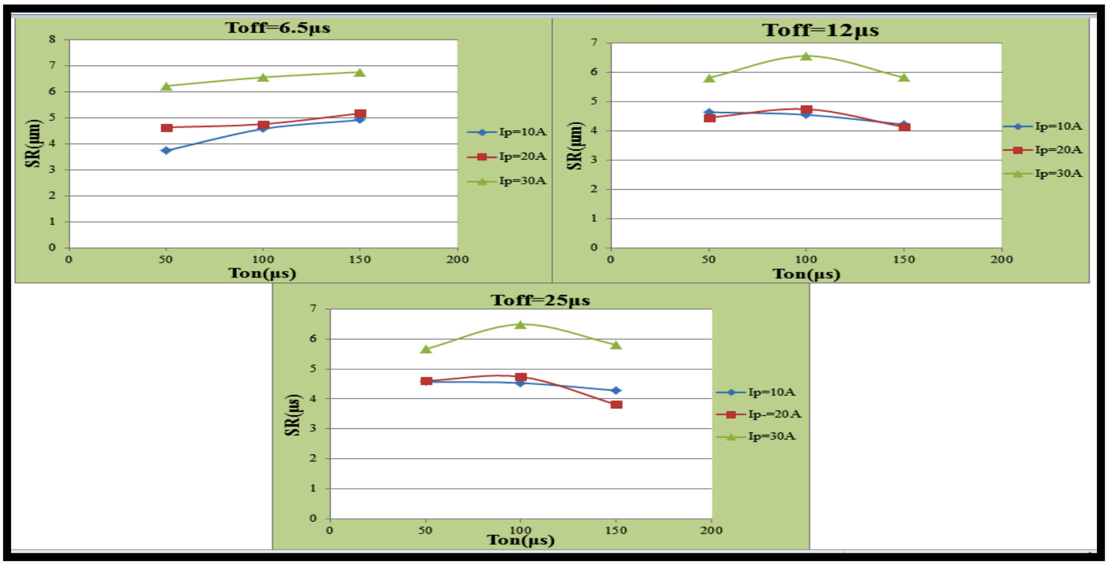


Figure 3: The effect of current, pulse on time and pulse off time on SR

MRR increasing with the increase in T_{on}, the causes were increasing discharge energy of the plasma channel and the longer period of transformation of this energy into the tool electrode, also, the MRR increase with increasing in current due to the production of the stronger spark that generates high temperature leading to melting and vaporization of materials and formation of a crater on the workpiece. While MRR decreases with increasing T_{off} because the dielectric liquid in the gap between the workpiece and tool electrode can't be flushed away properly and the debris particles still remain in the discharge gap and these results in arcing, due to which MRR decreases. Figure 4 Shown the effect of current, T_{on} and T_{off} on MRR.

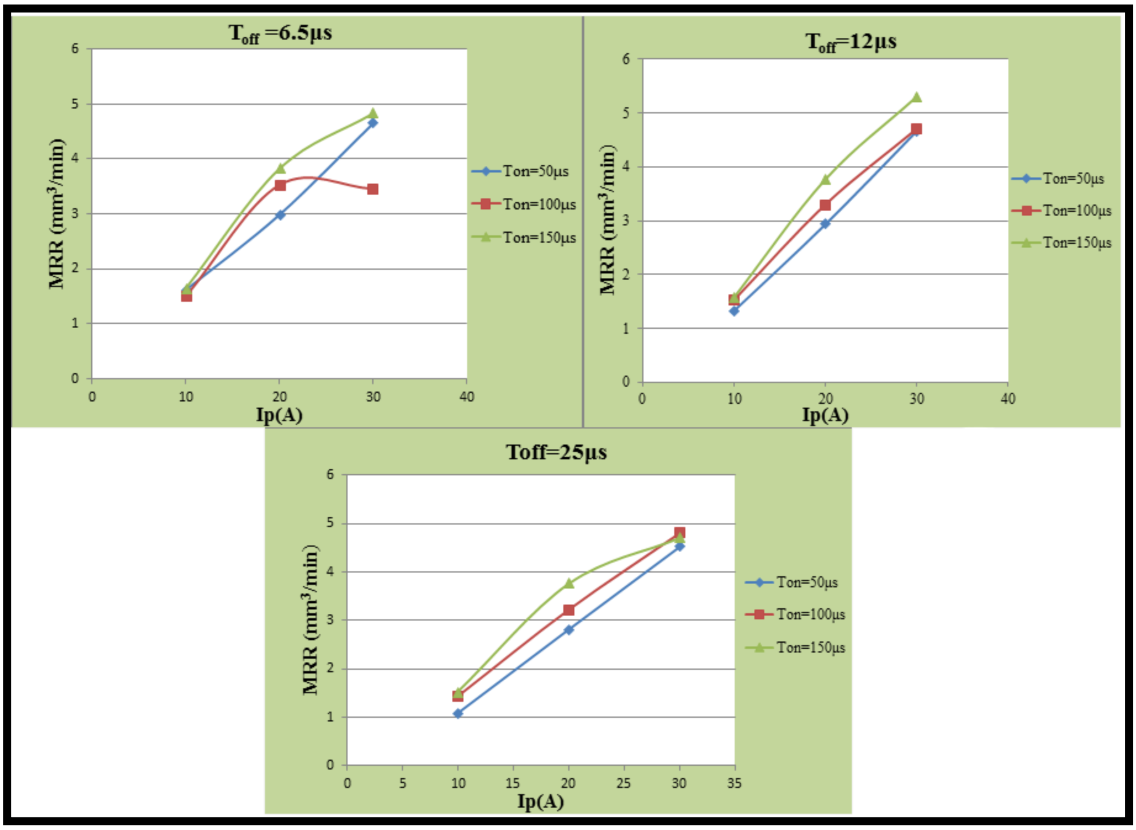


Figure 4: The effect of current, T_{on} and T_{off} on MRR

5. Conclusions

The present study discussed the effect of electrical process parameters (Current, Pulse on time and pulse off time) on the material removal rate and electrode wear rate for tool steel AISI L2 , when pure copper is used as a tool electrode. A Full factorial model is proposed to predict material removal rate and electrode wear rate value the result show that the experimented and predicted values are approximately equal. From the result we can conclude that:

- Best surface roughness for AISI L2 tool steel when cutting by electric discharge machine (EDM) occurred at a minimum value of (Current, Pulse on time and pulse off time) So to give high surface roughness using low current and pulse on time.
- The maximum or best Material removal rate is (5.3 mm^3/min) was occurred at maximum current and T_{on} (30A, 150µs) respectively. The minimum Material removal rate is (1.089mm^3/min) found at maximum pulse off time (25µs) and minimum current and Ton (10A, 50µs) respectively.

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