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Research Paper

EFFECT OF HEAT TREATMENT AND PROCESS PARAMETERS ON SURFACE ROUGHNESS IN WIRE ELECTRO DISCHARGE MACHINING

M M Dhobe[1]*, I K Chopde[2] and C L Gogte[3]

Corresponding Author: **M M Dhobe, ✉ m_dhobe@rediffmail.com*

Wire Electrical Discharge Machining (WEDM) is a nontraditional electro-thermal machining process capable of machining parts having complicated shapes and higher hardness. Materials having higher hardness are difficult to machine by traditional machining process. The technology on which WEDM works is conventional electro discharge sparking phenomenon widely accepted and implemented for industrial applications. In this paper, the effect of various heat treatment processes and machining parameters of WEDM like pulse on time (T_{ON}), pulse off time (T_{OFF}), gap voltage (S_V), peak current (IP) has been investigated to reveal their impact on surface roughness of tool steel AISI D2. During this research work, it is tried to investigate the effect of one variable at a time. The efforts are made to set the process parameters to minimize the surface roughness. The experimental studies were carried on Electronica Spring Cut WEDM machine and surface roughness is measured using Hommel Surface Roughness Tester T8000. It is observed that the surface roughness increases with increase in pulse on time (T_{ON}) and peak current (IP) while decreases with increase in number of tempering cycles after hardening for the same process parameters.

Keywords: Tool steel, Hardening, Tempering, WEDM, Surface roughness

INTRODUCTION

Due to the advancement in Engineering and technology demand for tool steel materials having higher hardness and impact resistance is increasing. Nevertheless these materials are difficult to machine using traditional methods. Hence, nontraditional machining methods such as Electro Discharge Machining and Wire Electro Discharge Machining (WEDM) are applied. Before designing the

[1] Mechanical Engg. Department, P E S College of Engineering, Aurangabad (M.S.), India.

[2] Mechanical Engg. Department, VNIT, Nagpur (M.S.), India.

[3] Mechanical Engg. Department, MIT, Aurangabad (M.S.), India.

dies, proper choice of tool steel is important to insure good performance. Tool steels are selected based on one of the property such as non deformability, toughness, Wear resistance, machineability and brittleness. Heat treatment is the process by which required properties can be inculcated in order to obtain the desired characteristics in the material. In Wire-EDM process a thin wire as an electrode is used to machine the surface The Wire-EDMed surface consists of many craters caused by electrical spark. The larger the electrical discharging energy, the worse is the surface quality. A large energy will produce a rippled surface and changes the structural and physical properties of the materials.

Many researchers have carried experiments by varying the machining parameters and analyzing the properties. It is observed that surface roughness is affected by Pulse duration and discharge current in w-edm. By decreasing the pulse duration and discharge current surface roughness can be improved (Rebelo *et al.*, 1998). Further it has been observed that if pulse energy per discharge is kept constant, short pulses and long pulses gives same surface roughness. However the surface topography and material removal rate will be different. The short pulse duration gives higher material removal rate than the long pulse duration (Ahmet and Ulas, 2004).

During W-edm enormous amount of heat generated causes local melting or even evaporating the work piece surface and electrode material. Similarly it causes the vaporization of dielectric fluid, which creates high pressure and forces the molten as well as vaporized material into finer particles in all directions. Continuous flow of dielectric fluid carries the droplets of metal away from the parent metal; however some of the molten metal solidified on work piece contributes to increasing the surface roughness (Bosheh and Mativenga, 2006; and Che-Chung *et al.*, 2009).

Experimentally it is observed that if the discharge energy is kept constant the short duration pulse and a high peak value discharge current removes the material by gasifying while a long duration pulse and low peak discharge current removes the material from the work piece by melting (Akhmedpasheav, 2007; and Choi *et al.*, 2008).

After multi cut WEDM the machined surface shows microstructure of fine martensitic behavior in tool steels due to rapid heating and instant cooling by dielectric fluid. After third and fourth cut a thin white layer composed of fine martensite and surface alloying in the work piece adjacent to the third and fourth cut surface was observed. The higher degree of surface alloying between wire electrode and work piece material was observed after fifth cut (Huang *et al.*, 2003).

In WEDM the parameters wire feed and wire tension have no effect on material removal rate. The pulse on time directly affects the material removal rate and surface roughness. Increase in pulse on time and peak current increases the material removal rate and decreases the surface roughness. It is further observed that due to increase in pulse off time and servo voltage decreases the MRR but improves the surface quality (Ashan *et al.*, 2006; and Sing and Garg, 2009).

EXPERIMENTAL METHODOLOGY

The machine used for experimentation work was "spring cut" Electronica Make Wire EDM as shown in the Figure 1. The test material used is AISI D2 steel and its composition is as shown in the Table 1.

Figure 1: Wire Electro Discharge Machine

Table 1: AISI D2 Material Composition

Element / AISI D2	C	Si	Mn	Cr	Mo	V
%	1.57	0.4	0.51	12.5	0.41	0.25

CuZn37 master brass wire with 0.25 mm diameter having tensile strength of 900 N/mm^2 was used as an electrode. De-ionized water (Ph Value 12.5) was used as the dielectric medium. The specimens of tool steel AISI D2 of 10 × 10 × 50 mm size were prepared by milling. The specimens are then heat treated in two different ways. The first one is Single Tempering (ST) after hardening and the other is Double Tempering (DT) after hardening. The heat treatment was then followed by W-EDM process to obtain 10 × 10 × 4 mm thick test pieces. During machining, the parameters, i.e., pulse interval time (16 μs), table feed rate (7.6 mm/min), Wire tension (1800 g), pulse current on, pulse Current off, and Voltage were kept constant. A surface finish Tester (Taylor Hobson make) was used to measure the surface roughness.

OBSERVATIONS

Number of experiments was conducted to find out the effect of input parameters on output parameter. During the experimentation the input parameters considered are pulse on time (T_{ON}), Pulse off (T_{OFF}), Servo voltage (S_v) and Peak current (I_p) one at a time are considered to find out its effect on out put parameter. The output parameter is Surface roughness. The change in output parameter due to change in input parameter is measured every time.

Effect of T_{ON}

In the first set of experiment pulse on time was varied from 105 units to 125 units in step of 5 units. All other parameters such as servo voltage, wire feed, peak current, and wire tension were kept constant. The variation in surface roughness due to variation in pulse on time is tabulated in the Table 2.

Table 2: Effect of T_{ON}

S. No.	Parameter	Ra μm	
	T_{ON} (Units)	Single Tempered	Double Tempered
1.	105	1.34	1.28
2.	110	2.21	1.51
3.	115	3.34	1.97
4.	120	3.39	2.17
5.	125	3.45	2.59

The other parameters kept constant during first set of experiment are: T_{OFF} = 40, Sv = 15, I_p = 70, W_f = 5, W_t = 9, S_f = 2100, Cc = 5, V_p = 2, W_p = 1, S = 20/12, Wire Dia. = 0.25 mm.

Effect of T_{OFF}

In the second set of experiment pulse off time (T_{OFF}) was varied from 40 units to 60 units in step of 5 units. All other parameters such as pulse on time, servo voltage, wire feed, peak current, wire tension were kept constant. The variation in surface roughness due to variation in pulse off time tabulated in Table 3 and is shown graphically in the Figure 3. The parameters kept constant during second set of experiment are: T_{ON} = 105, Sv = 15, I_p = 70, W_f = 5, W_t = 9, S_f = 2100, Cc = 5, V_p = 2, W_p = 1, S = 20/12, Wire Dia. = 0.25 mm.

Table 3: Effect of T_{OFF}

S. No.	Parameter	Ra µm	
	T_{OFF} (Units)	Single Tempered	Double Tempered
1.	40	2.56	2.47
2.	45	2.43	2.21
3.	50	1.92	1.71
4.	55	1.72	1.65
5.	60	1.34	1.28

Effect ofSv

In the third set of experiment servo voltage is varied from 15 units to 45 units in step of 5 units. All other parameters such as pulse on, pulse off time, wire feed, peak current, wire tension were kept constant. The variation in surface roughness due to variation in servo voltage is tabulated in the Table 4. The parameters kept constant during third set of experiment are: T_{ON} = 105, T_{OFF} = 40, I_p = 70, W_f = 5, W_t = 9, S_f = 2100, Cc = 5, V_p = 2, W_p = 1, S = 20/12, Wire Dia. = 0.25 mm.

Effect of I_p

In the fourth set of experiment peak current is varied from 70 units to 110 units in step of 10 units. All other parameters such as pulse on, pulse off time, wire feed, peak current, wire tension were kept constant. The variation in surface roughness due to variation in Peak current is tabulated in the Table 5 and is graphically shown in the Figure 5.

Table 4: Effect of Sv

S. No.	Parameter	Ra µm	
	Sv (Units)	Single Tempered	Double Tempered
1.	15	1.342	1.28
2.	20	1.287	1.22
3.	25	1.193	1.10
4.	30	1.180	1.08
5.	35	1.163	1.05
6.	40	1.154	1.04
7.	45	1.055	1.03

The parameters kept constant during fourth set of experiment are: T_{ON} = 105, Sv = 15, T_{OFF} = 40, W_f = 5, W_t = 9, S_f = 2100, Cc = 5, V_p = 2, W_p = 1, S = 20/12, Wire Dia. = 0.25 mm.

Table 5: Effect of I_p

S. No.	Parameter	Ra µm	
	I_p (Units)	Single Tempered	Double Tempered
1.	70	1.342	1.28
2.	80	1.564	1.78
3.	90	2.209	1.89
4.	100	2.183	1.67
5.	110	2.063	1.54

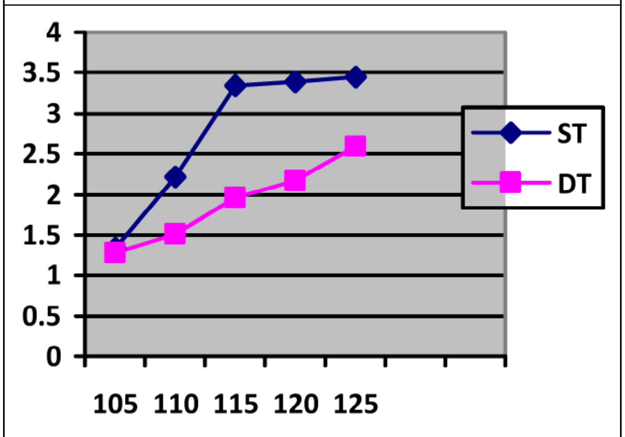
RESULT AND ANALYSIS

While conducting the various experiments during this study one factor experimental strategy was adopted. As per this strategy only one input parameter is to be varied at a time and all other input parameters are to be kept constant. During this experimental work in all twenty two experiments were conducted over two different types of test pieces. The various experimental results observed are analyzed and presented here.

The effect of pulse on time (T_{ON}) on the surface roughness is shown graphically in Figure 2.

The graph shows that the surface roughness obtained in double tempered test piece sample is lower than the values obtained in single tempered test piece samples. In both the cases surface roughness increases with increase in Ton value. The pattern of variation followed is nearly same in both the cases.

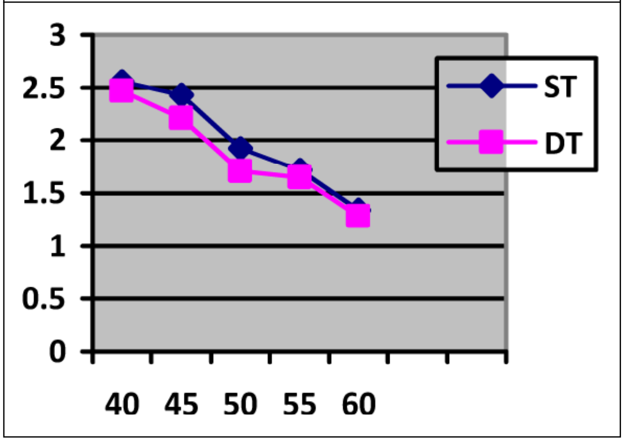
Figure 2: Effect of T_{ON} on Ra



Effect of T_{OFF} on Ra—for the second set of experiments the effect of pulse off time (T_{OFF}) on surface roughness is graphically shown in the Figure 3.

The graph shows that in both the cases surface roughness decreases with increase in pulse off time. The roughness values obtained in case of hardened and double tempered test piece are slightly lower or equal to the values obtained in case of single tempered test piece samples.

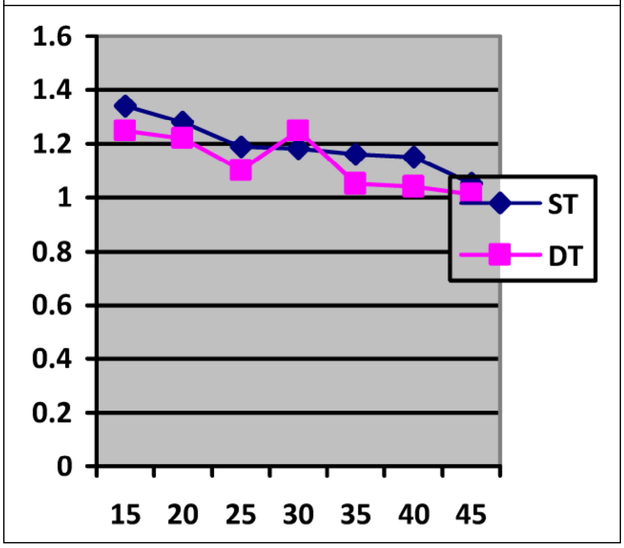
Figure 3: Effect of T_{OFF} on Ra



Effect of Sv on Ra—for the third set of experiments the effect of Servo voltage Sv on surface roughness is shown in the Figure 4.

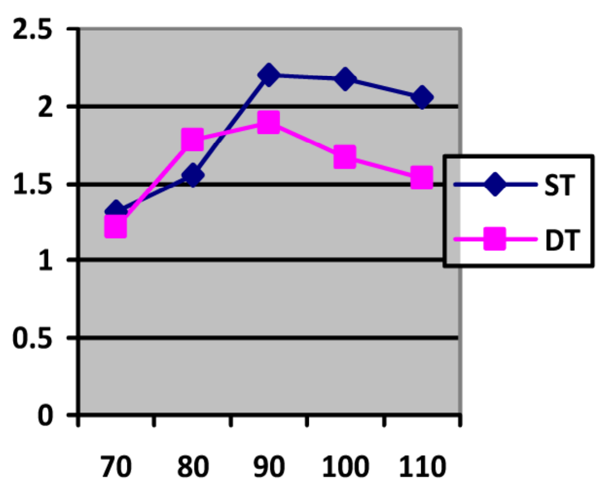
The graph shows that surface roughness decreases with increase in servo voltage. The roughness values obtained in double tempered test piece sample are lower than that of single tempered test piece.

Fig 4: Effect of Sv on Ra



Effect of peak current Ip—for the next set of experiment the effect of peak current on surface roughness is as shown in the Figure 5.

Figure 5: Effect of I_p on Ra



The graph shows that the roughness first slightly increases and then decreases with in crease in peak current. However the increase in roughness due to increase in peak current in case of double tempered test piece is less than that of single tempered test piece and the pattern of variation in roughness is near about same in case of both the type of test pieces.

CONCLUSION

On the basis of experimental study conducted and the result obtained the conclusions drawn are as follows:

- With increase in pulse on time surface roughness increases in both the type of test pieces. However for the same increasing values of pulse on time the surface roughness is lower in case of double tempered test piece than that of single tempered test piece samples.
- With the increase in pulse off time there is a continuous decrease in surface roughness in both the types of test pieces. Hardened and double tempered test piece gives lower surface roughness, however the difference in surface roughness values obtained in both the type of test pieces is very less.
- With the increase in servo voltage there is small decrease in surface roughness in case of both the types of test piece samples. It means that the surface quality improves with the increase in servo voltage.
- With the increase in peak current surface roughness increases in both the types of test pieces and afterwards it decreases. The surface roughness in double tempered test piece is lower than that of single tempered test piece.
- As a overall concluding remark we can say that the surface roughness increases with increase in Pulse on time and Peak current, while decreases with increase in pulse off time and servo voltage. Similarly double tempering after hardening reduces surface roughness compared to single tempering.

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