IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

AN EXPERIMENTAL INVESTIGATION OF MACHINING PARAMETERS ON ELCTRICAL DISCHARGE MACHINING OF M-250 (MARAGING) STEELS

Dr.T.Vijaya Babu*, Dr .J.S Soni, S. Ajaya Kumar

*Professor, Department of Mechanical Engineering, Vardhaman College of Engineering , Shamshabad , Hyderabad ,

Professor & Principal, Bharat Institute of Engineering and Technology , Ibrahimpatnam , Hyderabad

Assistant Professor , AVN Institute of Engineering and Technology , Ibrahimpatnam , Hyderabad

DOI: 10.5281/zenodo.187846

ABSTRACT

Maraging steel (M 250) exhibits high level of strength and hardness and possesses an extreme resistance to crack propagation, even in the most extreme environments. Optimization of present work is essential for effective machining. The present work is aimed at characterizing the electric discharge machining of maraging steels on EDM. 27 experiments are conducted by varying EDM parameters such as current, pulse-on-time, and duty factor. The performance measures like Material removal rate, surface roughness, and hardness are assessed. It is concluded that metal removal rate, and surface roughness increases with increase in current, duty factor. But, as the pulse-on-time increases MRR and surface roughness decreases. Hardness value increases as the current value increases from 5A to 10A amps and then decreases as the current increases from 10A to 15A. The same effect is observed as in case of duty factor and pulse on-time. Average crack length and recast layer thickness increases with increase in current and duty factor. But, there will be decreasing trend in case of pulse-on-time.

KEYWORDS: Electric discharge machining, machining parameters, Maraging steel, surface integrity

INTRODUCTION

Electric Discharge Machining (EDM) is a controlled material removal technique where by high frequency electric sparks are used to erode the work piece which takes a shape corresponding to that of the tool electrode. The cutting tool (electrode) is made from electrically conductive material, usually copper or graphite. The electrode made to the shape of cavity required, and the workpieces required are both submerged in a dielectric fluid which is a nonconductor of electricity. A servomechanism maintains a gap of about 0.01m to 0.02m between the electrode and the work, preventing them from coming into contact with each other. A direct current of low voltage and high amperage is delivered to the electrode at a frequency of several KHz producing sparks of similar frequency between the electrode and the work piece through the dielectric fluid.Intense heat is created in the localized area of spark impact, the metal melts or even vaporizes and gets expelled from the surface of workpiece. The dielectric fluid, which is constantly being circulated, carries away the eroded particles of metal during the off cycle of the pulse and also assists in dissipating the heat caused by the spark.

LITERATURE SURVEY

C.H. Kahng and K.P.Rajukar [1] found that the discharge time for the application of fine cutting conditions to improve the surface characteristics should not be estimated on the basis of surface geometry improvement only because the removal of white layer and heat affected zone including cracks requires considerable discharge time. The EDM of advanced ceramics has been widely accepted by the metal cutting industry owing to competitive machining costs and features. Koing, and Dauw [2] classified different grades of engineering ceramics as nonconductor, natural conductor and conductor. Sanchez et al.[3] provided a literature survey on the EDM of advanced ceramics, which has been commonly machined by ultrasonic machining (USM) and laser

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

beam machining (LBM), and proved the feasibility of machining Boron Carbide (B4C) and Silicon infiltrated Silicon Carbide (SiSiC) using EDM and wire electric discharge machining (WEDM). A combination of USM and EDM was also experimented to enhance the dielectric circulation in the spark gap, while machining ceramics with significant improvement in the performance measures and reduction in the thickness of the
white layer [4]. A lot of literature is found in case of die and tool steels, ceramics and metal matrix composites. But available literature on super alloys such as Ti-6Al-4V, and maraging steels (M250) is scanty. The present work is concentrated on M-250 which is extensively used in aerospace, automobile, shipbuilding, valves, pump shafts, heat exchangers etc. J.S. Soni and G. Chakraverti [5] have explained the migration of material elements between the electrode and work piece. The work piece used for this investigation is high carbon chromium die steel (T 215 Cr 12). They also studied the scanning electron microscope (SEM) investigation on changes in the chemical composition of resolidified layers of the tool and the workpiece as well as debris. The changes in chemical composition often remain confined to within resolidified layer which was supported by others [6]-[7]. O.A. Abu Zeid investigated the role of voltage, pulse-off-time in the electro discharge machined AISI T1 high speed steel [8]. He found that the MRR is not very sensitive to off-time changes at a low pulse-on-time corresponding to finish machining. Volumetric electrode wear has been found to be less with shorter off-times when finish machining but is independent of the off-time and direction of flushing. L.C. Lee, and L.C. Lim investigated the surface transformation and damage in AISI O1, A2, D2, and D6 steels after EDM [9]. According to them the electrical discharge machined surface of all the tool steels generally consists of three distinct layers the out most / white layer, an immediate layer and the unaffected parent layer. Pandey and Jilani [10] presented a thermal model on plasma channel growth and thermally damaged surface layer. They also drew the same conclusion that the EDMed surface has three distinct zones as that of Lee and Lim. Lim et al. [11] provided a review on the metallurgy of EDMed surface, which is dependent on the solidification behavior of the molten metal after the discharge cessation and subsequent phase transformation. The thickness of the recast layer formed on the work piece surface and the level of thermal damage suffered by the electrode can be determined by analyzing the growth of the plasma channel during sparking.EDMed surface has a relatively high micro hardness, which can be explained by the emigration of carbon from the oildielectrics to the work piece surface forming iron carbide in the white layer [12]. The concentration of carbides, both as surface layer on the work piece and as fine debris, is dependent on the frequency and polarity of the applied current together with other processing parameters such aspulse shape, gap spacing, and dielectric temperature [13]. Thompson argued that the pulse duration and type of electrode material under a paraffin dielectric has effect on the amount of carbon contamination [14].

EXPERIMENTAL DETAILS

The specification of Maraging steel is M 250 M- stands for high speed steel. The% of carbon in Maraging steel is 0.1%. Other elements are added to get the mechanical and physical strength.The Maraging steel metal is machined with the copper tool. Kerosene is the dielectric medium. 27 experiments are carried by varying EDM parameters such as current, pulse-on-time, and also duty factor while calculating the performance measures like MRR, SR, hardness and surface changes on each work piece. The major alloying elements in maraging steel are Nickel, Cobalt, Molybdenum, and Titanium. Maraging steel blocks were cut from the ingots. They were cut in to 27 pieces by tool and turret machine with dimensions of 20mmx8mmx5mm. The experiments were conducted on the material with copper electrode fig :1 depicts the work piece and tool combination. After the initial set up, machining parameters are selected according to the requirement. dielectric fluid is pumped into the tank above the specimen and then spark is switched on at predefined setting. Before machining each piece, the initial weight of the work is calculated by digital balance. After machining each piece is weighted and difference in weight is the MRR. Surface roughness is measured with talysurf and hardness is measured with Vickers hardness machine. Image analysis system is used to estimate the crack length, and thickness of recast layer of work pieces.

Fig 1: Work piece and tool

RESULT AND DISSCUSSIONS

The influence of current, pulse on-time, duty factor on the performance indices of EDM such as MRR, SR, hardness and surface changes is evaluated at different experimental conditions.

Table 1 : Variation of MRR with current and SR at constant pulse-on –time and duty factor

Exp. No	Current -A	Pulse-on –time(µs)	Duty factor (%)	MRR(mm^3/min)	Surface roughness (µs)
1	5	100	33.00	6.44	4.69
2	10	100	33.33	10.27	5.38
3	15	100	33.33	11.70	5.52
4	5	50	50	9.75	6.42
5	10	50	50	11.99	6.70
6	15	50	50	13.39	7.92
7	5	20	66.66	14.68	6.97
8	10	20	66.66	15.14	7.17
9	15	20	66.66	15.29	8.91

The relationship between MRR and current. It is observed that, when the current increases at constant pulse-on-time and constant duty factor, the MRR increases. When the current is increased from 5A to 10A the metal removal rate is increased with current. This means that, when current are higher, melting starts earlier i.e. low machining initiation time. It can be attributed that metal removal rate is proportional to the product of energy and pulse frequency .Increasing the pulse current at a constant frequency increases the energy of the pulse and ultimately higher metal removal rate. The surface roughness is increased with increase in current.

Table 2. Variation of MRR with duty factor at constant pulse-on –time

Exp. No	Current -A	Pulse-on –time(µs)	Duty factor (%)	MRR(mm^3/min)	Surface roughness (µs)
1	5	50	33.33	8026	4.22
2	10	50	50	9.72	4.26
3	15	50	66.66	11.01	5.70
4	5	20	33.33	9.43	5.22
5	10	20	50	14034	5.45
6	15	20	66.66	15.14	5.70
7	5	100	33.33	11.70	5.72
8	10	100	50	21.92	5.86
9	15	100	66.66	23.88	6.73

The relationship between metal removal rate and duty factor at constant current and pulse-on-time. When duty factor increases at constant current and constant pulse-on-time, material removal rate increases. It is also observed that at constant duty factor the material removal rate also increases with current. It can be noted that, the surface roughness is increased with increase in duty factor from 33.33% to 66.66%. This is due to the fact that at higher duty factor, increase in percent of machining time and increase in total current which automatically increases MRR will occur.

Table 3. Variation of MRR with pulse-on –time at constant current and duty factor

Exp. No	Current -A	Pulse-on –time(µs)	Duty factor (%)	MRR(mm^3/min)	Surface roughness (µs)
1	5	20	33.33	10.27	5.16
2	5	50	33.33	9.72	4.26
3	5	100	33.33	8.59	4.08
4	10	20	50	15.14	5.86
5	10	50	50	14.65	5.54
6	10	100	50	12.45	4.87
7	15	20	66.66	19.58	6.56

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

8	15	50	66.66	17.68	5.70
9	15	100	66.66	12.70	4.90

The relationship between metal removal rate and pulse-on-time at constant current and constant duty factor. The metal removal rate is decreased with increase inpulse-on-time. This is because of the short pulses which cause less vaporization, where as, long pulse duration cause the plasma channel to expand. The expansion of plasma channel cause less energy density on the work piece, which is insufficient to melt and/ or vaporize the work piece material.

Table 4. Variation of hardness with current at 20 pulse-on –time and 66.66% duty factor

Expt.no	Current A	Hardness (Hv)
1	5	261.1
2	10	912
3	15	821

The relationship between hardness and current at constant pulse-on-time and duty factor. The Vickers hardness value increases from 5A to 10 A and then decreases. When current increased from 5A to 10A more number of carbon particles are deposited on machined surface and hence, the hardness of the machined surface is increased, where as in case of 15A current, due to the high current, the carbon deposited on the machined surface is flushed out.

Table 5. Variation of hardness with pulse-on –time at 5A current and 50 % duty factor

Exp.No	Pulse –on –time	Hardness (Hv)
1	20	394.4
2	50	866.8
3	100	868

The relationship between the Vickers hardness value and Pulse-on-time at constant current and constant duty factor. Vickers hardness value increase with increase in pulse-on-time from 20µs to 100µs.This is due to the fact that, a long pulse duration causes the plasma channel to expand.

Table 6. Variation of hardness with duty factor at 15A current and 100µs of pulse-on –time

Exp. No	Duty factor	Hardness
1	33.33	198.8
2	50	900.3
3	66.66	604.1

The relationship between Vickers hardness and duty factor at constant current and constant pulse-on-time. When the duty factor increases from 33.33% to 50% the hardness value also increases due the deposition of carbon and then, the hardness value decreases at 66.66% due to the high duty factor, at which the carbon deposition layer is flushed out from the work piece.

SURFACE CRACKING

The depth of the cracks depends on the depth of decarburization. Immediate tempering after quenching, which prevents surface cracks, is necessary when there is a decarburized layer. When Maraging steel metal undergoes EDM operation, high temperature will be generated at the machining surface. When the current increases, the spark intensity also increases. Due to the increase in intensity of spark the temperature of the machining surface will also increases, so that when the current increases the crack length and crack width also increases. When the duty factor increases, the machining time and spark intensity also increases due to which crack length and width are also increases.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Expt.no	Current A	Average crack length (µs)
1	5	50.05
2	10	53.52
3	15	64.12

Table 7. Variation of avg crack length with current at 20 µs of pulse-on –time and 66.66%duty factor

The relationship between average crack length and current. The average crack length is increased with increase in current. When the discharge current is high ,the spark intensity and discharge power are more. Subsequently large amount of heat is generated on the surface of the work piece, which results in the thermal stresses developed and exceeds the strength of the material and so average crack length increases. Fig.2 depicts the images of cracks taken at different current values and constant duty factor.

Table 8. Variation of avg crack length with duty factor at 15 A current and 100µs of pulse-on –time

Expt.no	Current A	Average crack length (µs)
1	33.33	51.53
2	50	56.34
3	66.66	64.32

The values of average crack length at different values of duty factor. Fig.3 depicts the corresponding images taken.

Table 9. Variation of avg. crack length with pulse-on –time at 15 A current and 50& duty factor

Expt. No	Current A	Average crack length (µs)
1	20	35.07
2	50	25.79
3	100	20.69

The values of average crack length with different pulse-on-time and fig.4 shows the images. The average crack length is decreased with increase in pulse-on-time. When the pulse-on-time is increased, the intensity of plasma channel expands. Then, the spark intensity and discharge power are less, subsequently causing a less amount of heat generated on the surface of the work piece, which results in thermal stresses developed in the material to decrease, and finally resulting in the reduction of crack length.

Fig .2 variation of surface crack propagation at constant pulse-on-time 20 s and duty factor 66.66% by varying current 5A , 10A , 15A .

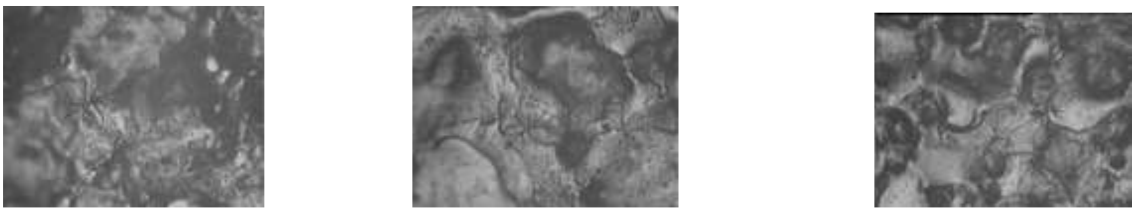

Fig .2 variation of surface crack propagation at constant pulse-on-time 20 s and duty factor 66.66% by varying current 5A , 10A , 15A .

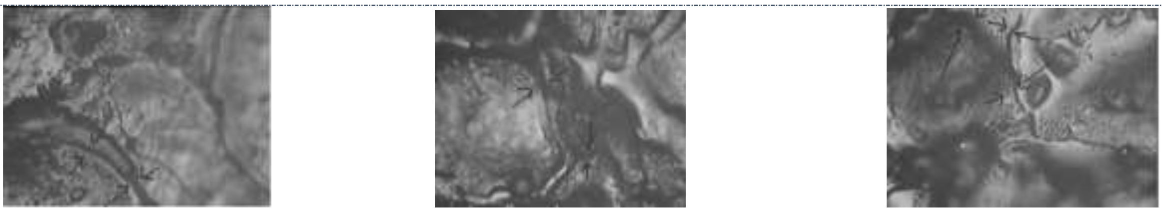

Fig .2 variation of surface crack propagation at constant pulse-on-time 20 s and duty factor 66.66% by varying current 5A , 10A , 15A .

CONCLUSION

When current increases, the MRR also increases. The higher the current, intensity of spark is increased and results in high metal removal rate. When the current is increased, surface roughness is also increased. When current increases, hardness will decrease. When current is increased, the crack length, crack widths are also increased due to the high temperature generation at high currents. When duty factor increases, the MRR is also increases. The higher the duty factor, intensity of spark increases which results in high metal removal rate. When the duty factor is increased, surface roughness is increased. Due to increase in duty factor, the spark intensity, machining time also increases resulting in the increase of MRR. Finally the surface roughness is increases. When duty factor increases, hardness will decrease. When duty factor is increased, the crack length, crack widths are also increased due to the high temperature generation. When pulse-on-time increases, the MRR is decreased. The higher the pulse-on-time, intensity of spark decreases due to expansion of plasma channel and results in less metal removal. When Pulse-on-time is increased, surface roughness is decreased. When Pulse-on-time increases, hardness will increase. When pulse-on-time is increased, the crack length, crack widths are increased due to the low temperature generation at high pulse-on-time due to the expansion of plasma channel. When the pulse-on-time increases the average crack length is decreased.

REFERENCES

1. C.H. Kahng and K.P. Rajaurkar, Michnigan Technological University, USA submitted by Prof.M.C. Shaw.
2. W. Koning , D.F Dauw , G. Levy, U. Panten, “EDM future steps towards the machining of ceramics,” *Ann. CIRP*, 37, 2, 1998 , pp.623-631.
3. J.A. Sanchez, I. Cabanes, L.N. Lopez de Localle, A. Iamaikiz, “Development of optimum electro discharge machining technology for advanced ceramics,” *Int J.Avd. Manuf.Technol.*, 18, 12, 2001, pp.891-905.
4. T.C. Lee, J.H Zhang, W.S. Lau, “Machining of engineering ceramics by ultrasonic vibration assisted EDM method,” *J. Mater. Manu Processes,* 13, 1, 1998,pp.133-146.
5. J.S. Soni, G. Chakraverti, “Experimental investigation of migration of material during EDM of die Steel (T215Cr12),” 1994. pp.51-58.
6. Koshy George, P.K. Philip and Geddam A, “Hardening of surface layers using electrical discharge techniques,” *Proc. Conf. 11th AIMTDR, IIT, MADRAS*, 1981, p. 315.
7. A. Gandadhar ,M.S. Shunmugam and P.K Philip,“Surface modification in electro discharge techniques with a powder compact tool electrode,” *Wear*, Vol. 143, No 1,1991, p.45.
8. O.A. Abu Zied, “The role of voltage pulse off-time in the electro discharge machined AISI T 1 high- speed steel,” *J. of Mat Process Technol.* 61, 1996,pp.287-291.
9. L.C. Lee, L.C. Lim, V. Narayanan and V.C Venkatesh,“Quantification of surface damage of tool steel after EDM,” Vol. 28, No 4, 1988, pp. 359- 372.
10. S.H. Lee, X.P. Li, “Study of the effect of machining parameters on the machining characteristics in electric discharge machining of tungsten carbide,” *Journal of Matl. Processing Technology,* 115, 2001, pp.344-358.
11. L.C. Lim, L.C. Lee, Y.S. Wong , H.H Lu, “Solidification microstructure of electro discharged machined surface of tool steels,” *Mater. Sci. Technol*,7, 1991, pp. 239-248.
12. J.P. Kruth, L. Stevens, L. Froyen, B. Lauwers, “Study of the white layer of a surface machined by die-sinking electro discharge machining,” *Ann.CIRP*, 44, 1,1995,pp. 169-172.
13. J.D. Ayers, K. Moore, “Formation of metal carbide powder by spark machining of relative metals,” *Metal. Trans. A*, 15A, 1984, pp.1172- 1127.
14. P.F. Thompson, “Surface damage in electro discharge machining,” *Mater. Sci. Technol.*, 5, 1989,pp.1153-1157