Investigation of Electric Discharge Machining of O6 Tool Steel Using Graphite Electrode

Harpinder Singh Sandhu[1], Gurpreet Singh Phull[1], Jai InderPreet Singh[1], Piyush Gulati[1], Rajeev Kumar[1]
[1]School of Mechanical Engineering,
Lovely Professional University, Phagwara-144411, Punjab, India

ABSTRACT

Electric Discharge Machining is a non-traditional machining process, used for machining of hard and tough materials, which are difficult to machine by traditional machining processes. The greatest difficulty of EDM is low material removal rate, high tool wear rate, surface roughness, end wear and corner wear. In this research work, an experimental investigation was performed to determine the mechanical properties of Angstrofine Graphite using negative polarization. The work presented in this paper is the effects of current decrease, pulse time (tone), and duty cycle on output parameters such as Material Removal Rate (MRR) and Surface Roughness(SR)

Keywords: Electrical Discharge Machining (EDM), Material Removal Rate (MRR), Surface Roughness (SR)

INTRODUCTION

In 1766, Joseph Priestley, an English theologian and chemist, first noted the craters formed on the cathode(metal) surface due to electric sparks. In 1943, two Russian brothers Boris and Natalya Lazarenko were the pioneers who used the electric spark to remove metal. Electrical Discharge Machining (EDM) is a non-conventional machining process used to remove metal by a controlled disintegration of electrically conductive materials by the commencement of fast and repetitive spark releases between the anode and workpiece isolated by a little distance. EDM is a vital and powerful method of machining electrically conductive materials which are extremely difficult and fragile. In this process the electrode and workpiece are always maintaining a distance between themselves; therefor operator need not have to worry about the cutting forces acting on workpiece [1]. A slight gap about 0.025mm is kept by a servo system shown in Figure 1inbetween the EDM tool and workpiece. Dielectric fluid is used to envelope the EDM tool and work piece in the work pan. EDM oil/ Kerosene/deionized water are normal kind of dielectric liquids although gaseous dielectrics are additionally utilized in specific cases. At the point when a distinction of potential is applied between two conductors submerged in a dielectric liquid the liquid will ionize if the potential contrast arrives at a sufficiently high worth, a spark will happen.

For the application requiring material parts having high melting point, toughness, hardness, brittleness, fragile and slender workpieces needing machining without distortion, the process that every industry use from tool room to big companies in every filed like tool and die, automobile, aerospace and electronics industries is Electric Discharge Machining for production of prototype and parts where the quantities are relatively low.

Singh et al. [2] carried out study of electrode wear rate, material removal rate, surface roughness and radial overcut on EN31 Tool Steel using different tool material and found copper electrode best due to minimum surface roughness, electrode wear rate and radial overcut and maximum material removal rate. Lee et al. [3] carried out study of material removal rate and electrode wear rate on Tungsten Carbide using Copper, Copper Tungsten and Graphite electrodes and found Copper Tungsten best due to maximum material removal rate and minimum electrode wear rate. Janmanee et al. [4] carried out study on the effect of the duty factor, polarity and current on material removal rate, electrode wear rate, surface finish and micro crack density. They found that electrode with negative polarity performs well and maximum material removal rate and electrode wear rate were achieved by increasing the discharge current. Pandey et al. [5] carried out study to optimize the various process parameters for maximum MRR and minimum surface roughness on ceramic material. Abdulkareem et al.[6] research reveled that with increase in discharge current their will be increase in material removal rate, surface roughness and radial overcut for Copper Graphite tool on AISI 1045 alloy Steel. Mohandass et al. [7] used Copper electrode to get improved material removal rate and radial overcut.

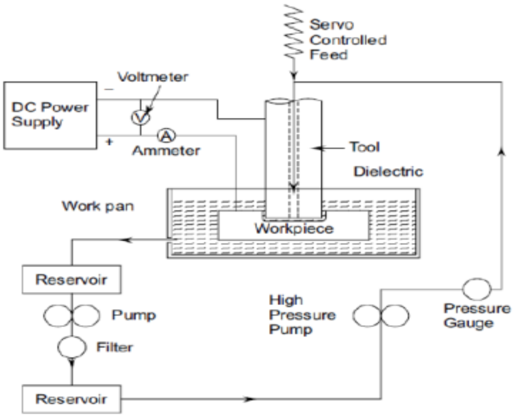

Figure 1: Set up of EDM. [1]

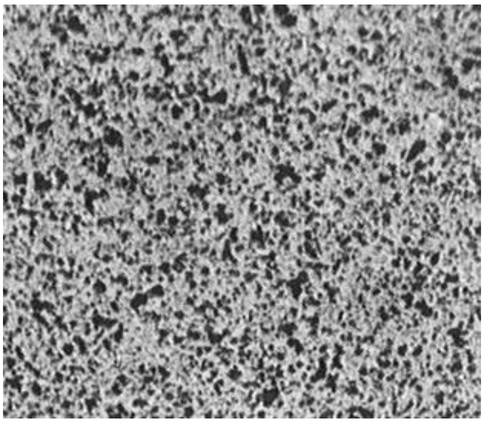

Figure 2: Microstructure of Angstrofine Graphite

EXPERIMENTAL PROCEDURE AND PARAMETERS

The experiments have been conducted on a numerically controlled (NC) die-sinking EDM Machine of Electronica India make. Sparkonix machine is servo controlled by an NC code programming and the servo control feedback is dependent on the gap voltage between the electrode and workpiece. Electrode material used for these experiments are Angstrofine(AF) Graphite having an average particle size of less than one micron size is used. The AF Graphite electrode is having isotropic grain structure resulting in very high strength, good wear resistance and finer surface finishes. The figure 2 shows the microstructure of AF Graphite, the black region in the figure shows porosity and grey region/ lighter region shows graphite particles. AF Graphite has low electrical resistivity and good thermal resistance, which results in a more efficient energy transfer to the workpiece. AF Graphite is recommended for application such as fine detailed engraving, deep grooves and were surface finish is of prime importance. The essential properties of AF graphite are shown in table 1. Electrodes were fabricated into a cubical shape of 25 mm X 25 mm X 50 mm with a cylindrical hole drilled centrally for flushing.

Table 1: Properties of Angstrofine Graphite

Particle Size (µm)	Density (g/cc)	Flexural Strength (N/mm^2)	Compressive Strength (N/mm^2)	Hardness (Shore)	Electric Resistivity (µ ohm cm)	Thermal Conductivity (watts/mk)
<1	1.95	100	152	83	850	130

The workpiece used in the experiments is Tool Steel O6. Tool Steel O6 is a graphitic tool steel with excellent metal to metal galling and sliding resistance. Graphite particles are uniformly dispersed in steel, which provide excellent machinability and metal to metal wear resistance characteristics. Oil is retained in lubricating environment due to Graphite particles. Alloying elements of the O6 Tool Steel are listed in the Table2. The essential properties of O6 Tool Steel are listed in Table 3.

Table 2: Chemical Composition of O6 Tool Steel

Alloying Element	Carbon	Manganese	Silicon	Molybdenum	Iron
%	1.45	0.85	1.00	0.25	Balance

Table 3: Physical Properties of O6 Tool Steel

Density (g/cm^3)	Poission's Ratio	Elastic Modulus (kN/mm^2)	Bulk Modulus (kN/mm^2)	Shear Modulus (kN/mm^2)	Hardness (Rockwell)	Coefficient of Expansion (mm/m °C)
7.67	0.27-30	200	140	80	65	12.48

During EDM processing, each cycle had an activation time (Ton) and a deactivation time (Toff), which is displayed in microseconds. Since all work is done on- time, the total duration of these pulses and their frequencies are of great importance. In order to observe the effect of the pulse activation time on the MRR and SR the maximum current value is changed but other parameter are fixed, such as pulse off time, control voltage, and feed rate of electrodes. The discharge energy applied during Ton is directly proportional to the MRR [8]. The pulse off time allows the dielectric fluid to produce a cooling effect and remove small molten particles from the space between the tool and the workpiece. The surface roughness decreases with increasing first stop time, and then increases with increasing pulse stop time [9]. The maximum current is the most important processing parameter and is the amount of power (measured in amperes) used in spark processing; higher current will improve MRR, but at the expense of surface roughness [10-13].

The machine used for experimentation is numerical control die sinking EDM of Electronica F series from India. Machine is equipped with mean voltage (MV) servo for finish machining. This work used AF Graphite as electrode material which is employed to get best possible surface finish and for the workpiece uses O6 Tool Steel which is employed for manufacturing of various machine tool parts. Kerosene oil is used as a dielectric fluid. The effect of various parameters of the EDM process, such as current, on-time, polarity, and duty cycle on the MMR, final wear, and surface quality, was determined experimentally. After setup, various processing parameters are selected, as shown in Table 4. The dielectric fluid is pumped through the center hole of the electrode, and then a spark is ignited. After the experiment, was measured using a portable MITUTOYO SJ-210P instrument was used to measure the surface roughness value Ra which is the arithmetical average of the roughness.

Table 4: Experimental Condition

Experimental Conditions	**Descriptions**
Workpiece	O6 Tool Steel
Electrode	Angstrofine Graphite
Polarity	(-)
Current(A)	2.5, 3.5, 5.5
Ton	2, 12, 51
Duty Factor %	33, 50, 67
Dielectric fluid	Kerosene oil

RESULT AND DISCUSSIONS

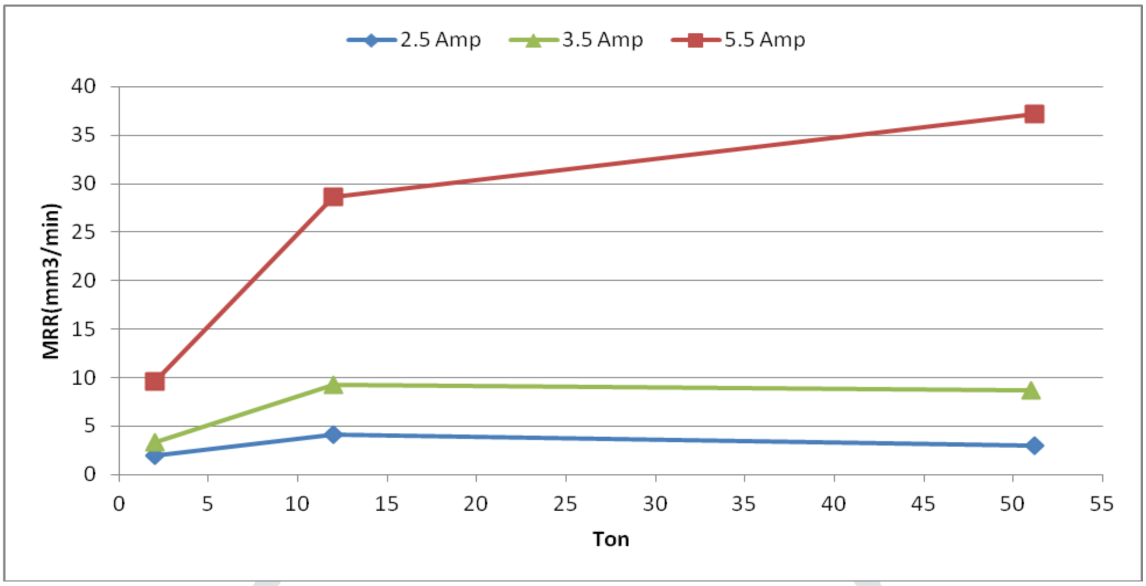

Figure 3: MRR at various values of discharge current

Figure 3 shows the relationship between discharge current, Ton and MRR. The MRR increses with increase in Ton at all values of current. At the begning at low value of current , insufficient heating of the work material leads to the low MRR and with increase in current the MRR also increases because the workpieace temperature is raised or easily exceed the boiling point.For current value of 2.5 Amp and on-time of 2 µs, we get minimum MRR of 1.923 mm^3/min and for value of 8 Amp and on-time of 51 µs, we get maximum of 38.18 mm^3/min. The MRR increases sharply with increasing discharge current from 2.5 to 8 Amp and it increase sharply when on-time increase from 2 to 12 µs and there is slight change their after.

Figure 4 shows the relation between current and surface roughness of the workpiece, with increase in discharge current and on-time the surface roughness increases. It has been observed that the surface roughness with a low pulse duration value and a high peak current value is less than the high pulse duration value and a low peak current value. The current leading to the least surface roughness (Ra) was 2.5 Amp, and the Ra value was 0.77 µm. The results of the experiment showed that a variation of the discharge current led to insignificant differences in the surface roughness, with the highest values of the current leading to Ra value of 3.18 µm.

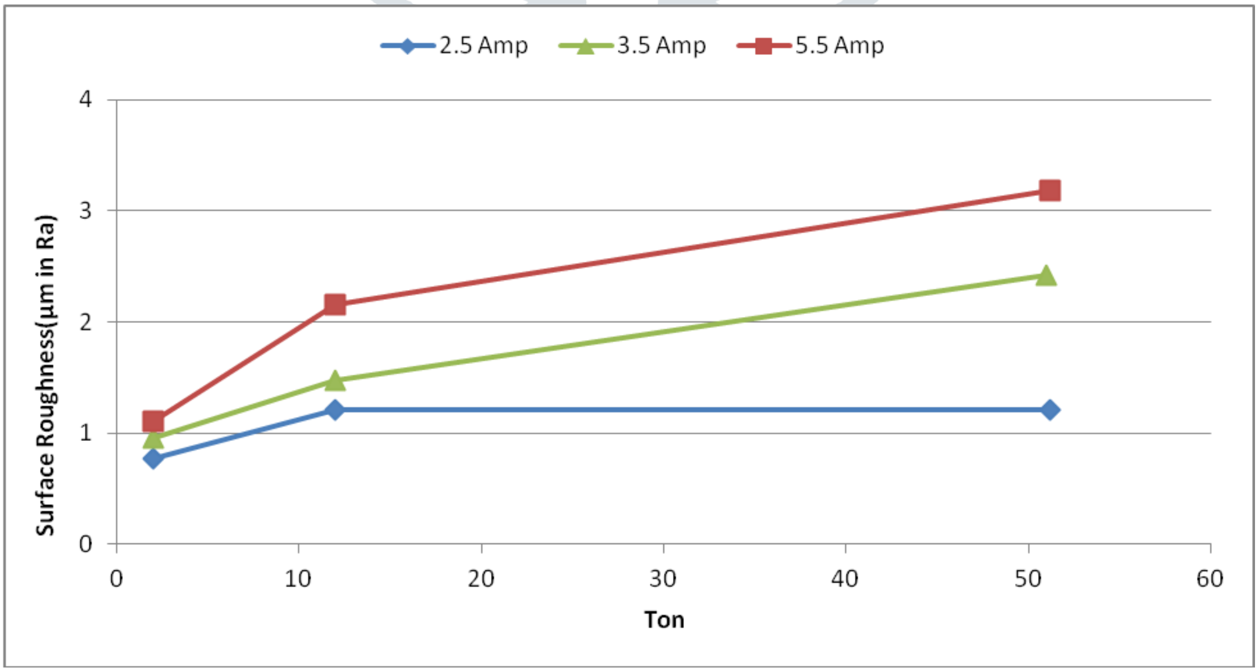

Figure 4: SR at various values of discharge current

CONCLUSION

From this research, it can be deduced that the electrode tool with negative polarity works better in terms of high MRR and less wear of the tool. The discharge current and ton values had a direct impact on the MRR and the surface finish, the higher the discharge current the higher the MRR and SR and vice versa. The highest MRR is reached when the discharge current is highest and when the Ton is highest. In addition, the discharge current and ton values inversely affect the smoothness of the surface that is to say that when the discharge current and the Ton are higher, the surface roughness is found to be maximum. A minimum surface roughness of 0.774 µm is achieved on least amperage of 2.5A and Ton of 2 µs, whereas, maximum MRR of value 38.18 mm^3/min was achieved on 8.5A current discharge and 51.2 µs Ton.

REFERENCES

[1] P.N. Rao,"Manufacturing Technology, Vol-2", pp. 296, 2nd Ed (2012).

[2] Singh, S., Maheshwari, S., Pandey, P.C., "Some Investigation into the Electric Discharge Machining of Hardened Tool Steel Using Different Electrode Materials. Journal of Materials Processing Technology", 149 (1-3), pp. 272-277 , 2004.

[3] Soo Hiong Lee, Xiaoping Li," Study of the Surface Integrity of the Machined Workpiece in the EDM of Tungsten Carbide" Journal of Materials Processing Technology 139, pp. 315321, 2003.

[4] Janmanee, P., Muttamara , A., "Optimization of Electrical Discharge Machining of Composite 90WC-10Co Base on Taguchi Approach", European Journal of Scienctific Research, 64 (3), pp. 426-436, 2011.

[5]Anand Pandey and Shankar Singh, "Current Research Trends in Variants of Electrical Discharge Machining: A review", Vol.2(6), 2172-2191, 2010.

[6] Suleiman Abdulkareem, Ahansan Ali Khan and Mohamed Konneh, "Cooling Effect on Electrode and Process Parameters in EDM", Materials and Manufacturing Process, 462-466, 2010.

[7] R Mohandoss,"Mechanical Behaviour of Cryogenically Treated EN-19 Alloy Steel", International Journal of Power Control Signal and Computation" vol. 1, 2012.

[8]H.K. Kansal, Sehijpal Singh, P. Kumar, "Parametric optimization of powder mixed electrical discharge machining by response surface methodology". Journal of Materials Processing Technology, Vol.169(3), 427–436, 2005.

[9] Simao J., Lee H.G., Aspinwall D.K., Dewes R.C. and Aspinwall, E.M.,"Work piece surface modification using electrical discharge machining", Int. J. Mach. Tool & Mfg., vol. 43(2), 121-128, 2003.

[10] Shitij Sood, "Effect of Powder Mixed Dielectric on Material Removal Rate, Tool Wear Rate and Surface Properties in Electric Discharge Machining" Thesis, 2008.

[11] Ravinder Kumar, Abhishek Singh and Inderdeep Singh, "Electric discharge hole grinding in hybrid metal matrix composite", Materials and Manufacturing Processes, 32:2, 127–134, 2017.

[12] Ravinder Kumar and Inderdeep Singh, "Electric discharge sawing of hybrid metal matrix composites", Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 231 (10), 1775-1782, 2017.

[13] Ravinder Kumar, Inderdeep Singh and Dinesh Kumar. "Electro discharge drilling of hybrid MMC", Procedia Engineering, 64, 1337–1343, 2013.