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Investigation on the Material Removal Mechanism and the Thermal Aspects in the Electrical Discharge Machining Process

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ABSTRACT

The aim of this paper is to study the Electro discharge machining process. EDM has been an important manufacturing process for the tool, mould, and dies industries for several decades. The process is finding an increasing industrial use owing to its ability to produce geometrically complex shapes as well as its ability to machine hard materials that are extremely difficult using conventional processes. Further, in spite of the recent technical advancement, the conventional machining processes are inadequate to produce complex geometries shapes in hard and temperature resistant alloy and die steels. Keeping these requirements in mind, EDM a non conventional machining methods have been developed. The current study defines operating principles as discharging sparks, vapour, and erosion processes using heat energy to process parts.

Keywords: *EDM, Sparking, Dielectric, MRR, Erosion, Discharge*

1. INTRODUCTION

Industrial technology progress introduces a variety of superior materials. These materials have better mechanical characteristics such as higher toughness, more strength, more hardness, and a higher melting point for example Carbon–carbon composites are highly potential materials in aeronautical and aerospace industries because of their favourable properties like high strength, high service temperature, high stiffness and low density [13–16]. However, they are difficult to machine materials by the conventional machining methods, which limits their use. In order to make parts of the required specifications an appropriate machining method is to be selected. Among the various non-conventional machining methods available, EDM is the most widely used and successfully applied one for the difficult to machine materials [17–19].Therefore, non-traditional manufacturing technologies such as electrical discharge machining (EDM) need to be applied (Weller, 1984). There is no direct contact occurs between electrode and work piece so no stress is created in the processed material. The work piece for processing can consist of any materials as long as the materials have good electrical conductivity. Therefore, EDM applies widely for processing difficult materials since it performs with superior machining characteristics (Ho and Newman, 2003) [7][9].

2. MECHANISM OF MATERIAL REMOVAL IN EDM PROCESS

In EDM, the material is removed primarily through the conversion of electrical energy into thermal energy through a series of successive sparks between the electrode and the work piece in a dielectric fluid. The thermal energy is consumed in generating high temperature plasma, eroding the work piece material [11]. Metal removal takes place as a result of the generation of extremely high temperatures generated by the high-intensity discharges that melt and evaporate the two electrodes. A series of voltage pulses (Fig. 2) of magnitude about 20 to 120 V and frequency on the order of 5 kHz is applied between the two electrodes, which are separated by a small gap. When the electrons and the positive ions reach the anode and cathode, they give up their kinetic energy in the form of heat. Temperatures of about 8000 to 12,000°C and heat fluxes up to 1017 W/m2 are attained.

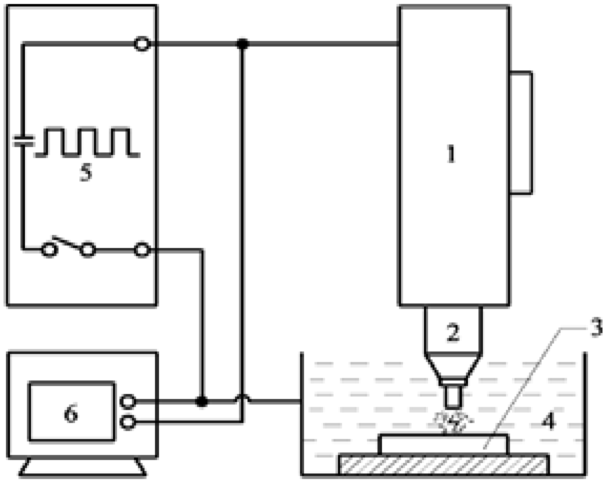

Figure 1: schematic diagram of the EDM process

1. Servo-control, 2. Electrode, 3. Work piece, 4. Die-electric fluid, 5. Pulse generator, 6. Oscilloscope

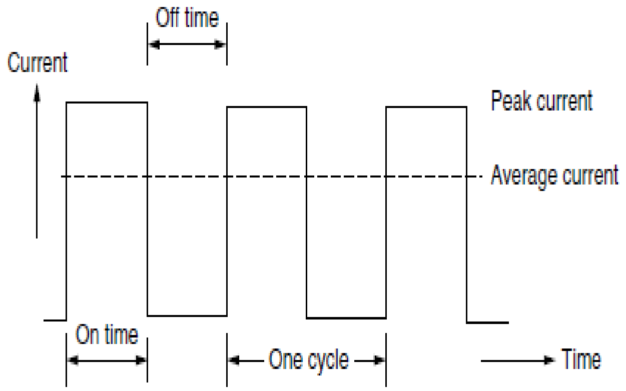

Figure-2 Typical EDM pulse current train for controlled pulse generator

With a very short duration spark of typically between 0.1 to 2000 μs the temperature of the electrodes can be raised locally to more than their normal boiling points. Owing to the evaporation of the dielectric, the pressure on the plasma channel rises rapidly to values as high as 200 atmospheres. Such great pressures prevent the evaporation of the superheated metal. At the end of the pulse, the pressure drops suddenly and the superheated metal evaporates explosively. Metal is thus removed from the electrodes as shown in figure-3.

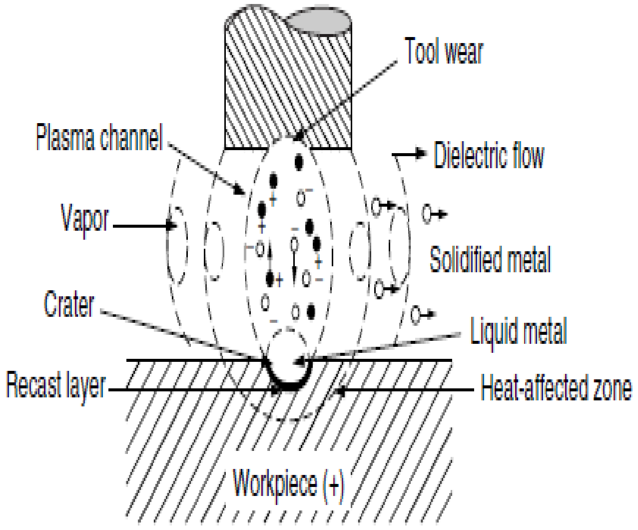

Figure-3 EDM Spark Description

The frequency of discharges or sparks usually varies between 500 and 500,000 sparks per second. With such high sparking frequencies, the combined effects of individual sparks provide a substantial material removal rate. The position of the tool electrode is controlled by the servomechanism, which maintains a constant gap width (200–500 μm) between the electrodes in order to increase the machining efficiency through active discharges. EDM performance measures such as material removal rate, electrode tool wear, and surface finish, for the same energy, depends on the shape of the current pulses.

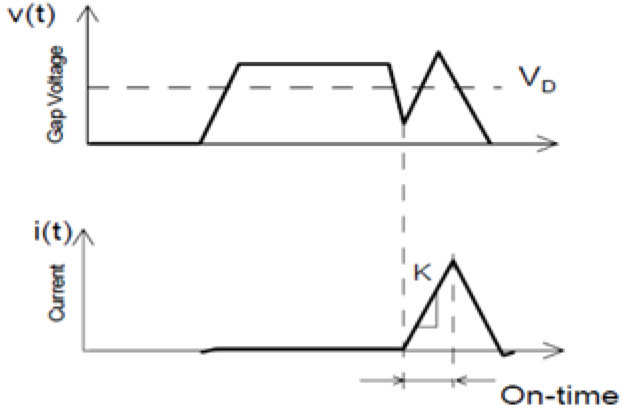

Figure-4 Voltage and Current Waveforms during EDM

Based upon the situation in the inter electrode gap, four different electrical pulses are distinguished, namely, **open circuit pulses, sparks, arcs, and short circuits.** They are usually defined on the basis of time evolution of discharge voltage and/or discharge current. Their effect upon material removal and tool wear differs quite significantly.

Electrode Material

Thus the basic characteristics of electrode materials are: High electrical conductivity – electrons are cold emitted more easily and there is less bulk electrical heating. High thermal conductivity – for the same heat load, the local temperature rise would be less due to faster heat conducted to the bulk of the tool and thus less tool wear. Higher density – for the same heat load and same tool wear by weight there would be less volume removal or tool wear and thus less dimensional loss or inaccuracy. High melting point – high melting point leads to fewer tools wear due to less tool material melting for the same heat load and easy manufacturability The different electrode materials which are used commonly in the industry are Graphite ,Electrolytic oxygen free copper , Tellurium copper – 99% Cu + 0.5% tellurium and Brass.

Process Parameters

Discharge Voltage

Discharge voltage in EDM is related to the spark gap and breakdown strength of the dielectric. Before current can flow, the open gap voltage increases until it creates an ionization path through the dielectric. Once the current starts to flow, voltage drops and stabilizes at the working gap level. The present voltage determines the width of the spark gap between the leading edge of the electrode and work piece. Higher voltage settings increase the gap, which improves the flushing conditions and helps to stabilize the cut. MRR < TWR and surface roughness increases with increasing open circuit voltage because electric field strength increases.

Peak Current

This is the amount of power used in discharge machining, measured in units of amperage and is the most important machining parameter in EDM. During each on-time pulse, the current increases until it reaches a preset level, which is expressed as the peak current. Higher currents will improve MRR but at the cost of TWR and surface finish, fig.5 shows the effect of current on surface.

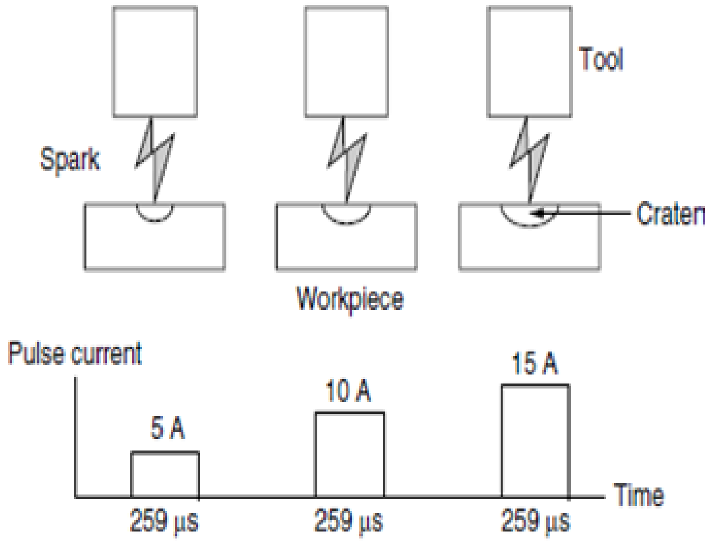

Figure-5: Effect of Pulse Current on Removal Rate and Surface Roughness

Pulse On-time and Off-time

Each cycle has an on-time and off-time that is expressed in units of microseconds. Since all the work is done during on-time, the duration of these pulses and the number of cycles per second are important. Metal removal is directly proportional to the amount of energy applied during the on-time. The resulting crater will be deep and broader than a crater produced by a shorter on-time. Excessive on-times can be counterproductive when the optimum on-time for each electrode-work material combination is exceeded, material rate starts to decreases.

The cycle is completed when sufficient when sufficient off-time is allowed before the start of the next cycle. Off-time will affect the speed and stability of the cut. Shorter the off-time, the faster will be the machining operation. However, if the off-time is too short, the ejected work piece material will not be swept away by the flow of the dielectric and the fluid will not be deionized. This will cause the next spark to be unstable. Unstable conditions cause erratic cycling and retraction of the advancing servo. This slows down cutting more than long, stable off-times. Off-time must be greater than the deionized time to prevent continued sparking at one point.

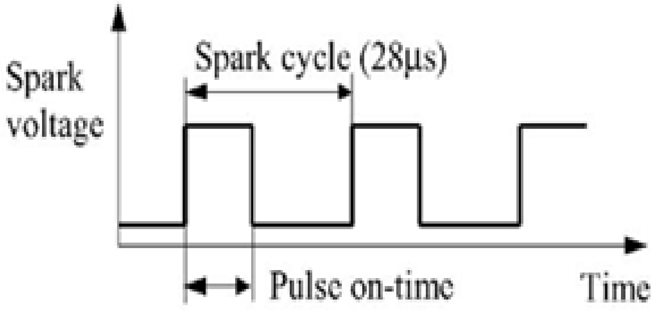

Figure-6: Spark voltage and Time waveform

Polarity

The polarity of the electrode can be either positive or negative. The current passing the gap creates high temperatures causing material evaporation at both electrode spots. As the electron processes show quicker reaction, the anode material is worn out predominantly. This causes minimum wear to the tool electrodes and becomes of importance under finishing operations with shorter on-times. However while longer discharges, the early electron process predominance changes to positron process, resulting in high tool wear.

Frequency

This is a measure of the number of times the current is turned on and off. During roughing, the 'on time' is increased significantly for high removal rates and fewer cycles per second. Frequency is distinct from the duty cycle, as this is a measure of efficiency.

Heat-Affected Zone

In EDM, with the temperature of the discharges reaching 8000 to 12,000°C, metallurgical changes occur in the surface layer of the work piece. Additionally a thin recast layer of 1 µm at 5-µm powers to 25 µm at high powers is formedSome annealing of the work piece can be expected in a zone just below the machined surface. In addition, not all the work piece material melted by the discharge is expelled into the dielectric. The remaining melted material is quickly chilled, primarily by heat conduction into the bulk of the work piece, resulting in an exceedingly hard surface.

The depth of the annealed layer is proportional to the amount of power used in the machining operation. It ranges from 50 µm for finish cutting to approximately 200 µm for high metal removal rates. The amount of annealing is usually about two points of hardness below the parent metal for finish cutting.

Choosing electrodes that produce more stable machining can reduce the annealing effect.

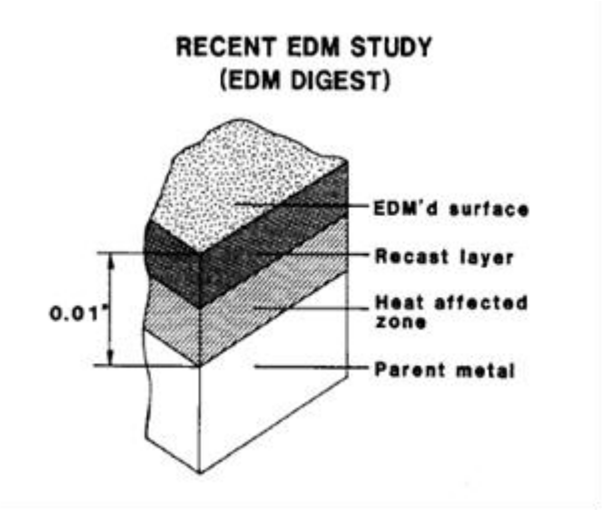

Figure-7: EDM Heat Effected Zones

Applications

EDM produces complex shapes to a high degree of accuracy in difficult-to-machine materials such as heat-resistant alloys, super alloys, and carbides. The incorporation of EDM within a computer integrated manufacturing (CIM) system reduced the length of time that the unit operation, without stops for maintenance, is required. Micromachining of holes, slots, and dies; procedures for surface deposition; modification; texturing; milling; and mechanical pulsing are typical applications which are shown in below diagram

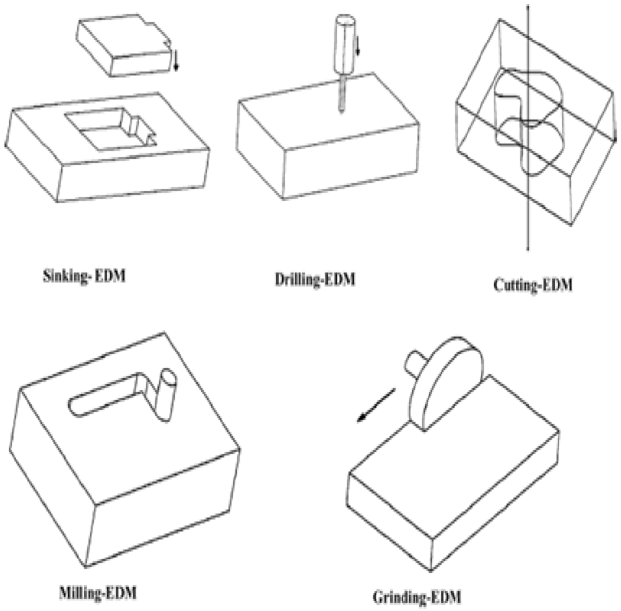
Sinking- EDM
Drilling-EDM
Cutting-EDM
Milling-EDM
Grinding-EDM

Figure-8: Various Applications of EDM

Machining of Dies and Moulds

EDM milling uses standard cylindrical electrodes. Complex cavities are machined by successive NC sweeps of the electrode down to the desired depth. The simple-shaped electrode is rotated at high speeds and follows specified paths in the work piece like the conventional end mills. This technique is very useful and makes EDM very versatile like the mechanical milling process. The process solves the problem of manufacturing accurate and complex-shaped electrodes for die sinking of three-dimensional cavities. EDM milling enhances dielectric flushing due to the high-speed electrode rotation. The electrode wear can be optimized because of the rotational and contouring motions of the electrode. The main limitation in the EDM milling is that complex shapes with sharp corners cannot be machined because of the rotating tool electrode. EDM milling also replaces the conventional die making that requires the use of a variety of machines such as milling, wire cutting, and EDM die sinking machines.

Prototype Production

EDM process is becoming a common method of making prototype and production parts, especially in the aerospace, automobile and electronics industries in which production quantities are relatively low. In Sinker EDM, a graphite, copper tungsten or pure copper electrode is machined into the desired (negative) shape and fed into the work piece on the end of a vertical ram.

Wire EDM

Wire EDM is a special form of EDM which uses a continuously moving conductive wire electrode. Material removal occurs as a result of spark erosion as the wire electrode is fed, from a fresh wire spool, through the work piece. Remarkable application includes the machining of super hard materials such as polycrystalline diamond (PCD) and cubic boron nitride (CBN) blanks, and other matrix composites.

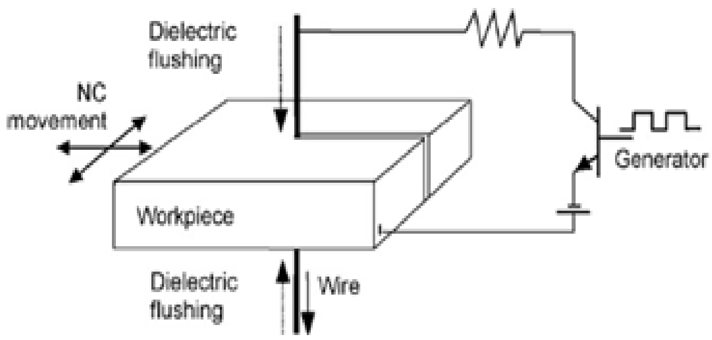

Figure-10: Wire EDM Schematic

CONCLUSIONS

1. The unconventional machining methods promise formidable tasks to be undertaken and set a new record in the manufacturing technology. These methods are not limited by hardness, toughness and brittleness of the material and can produce any intricate shape on any work material by suitable control over the various physical parameters of the process.
2. The surface roughness increased as the ‘peak current’ and ‘pulse on time’ increased using the reverse polarity.
3. The material removal rate was found to be more using straight polarity as compared to reverse polarity in the process.
4. The scanning electron microscope study of powder mixed electric discharge machining process showed that the cavities produced were shallow and uniform.
5. NTM processes are usually well suited to be monitored and controlled, the processing steps are reduced, the fixtures are simplified due to their inherent non-contact nature. In many cases, traditional manufacturing may have reached their capability limits, while NTM is offering the best solution.

REFERENCES

[1] J.A. Sanchez , J.L. Rodil , A. Herrero , L.N. Lopez de Lacalle , A. Lamikiz , On the influence of cutting speed limitation on the accuracy of wire-EDM corner-cutting, Journal of Materials Processing Technology 182 (2007) 574–579

[2] Jun Qu, Albert J. Shih , Ronald O. Scattergood , Jie Luo , Abrasive micro-blasting to improve surface integrity of electrical discharge machined WC–Co composite, Journal of Materials Processing Technology 166 (2005) 440–448

[3] Y.S. Liao , Y.P. Yu , The energy aspect of material property in WEDM and its application, Journal of Materials Processing Technology 149 (2004) 77–82

[4] B. Chandrasekhar Abothula, Vinod Yadava, and Gyanendra Kumar Singh, Development and Experimental Study of Electro discharge Face Grinding, Materials and Manufacturing Processes, 25: 482–487, 2010

[5] Y. H. Guu, C. Y. Chou, and Su-Tang Chiou, Study of the effect of machining parameters on the machining characteristics in Electrical Discharge machining of Fe-Mn-Al Alloy, Materials and Manufacturing Processes, 20: 905–916, 2005

[6] Yan-Cherng Lin1, Yuan-Feng Chen1, Ching-Tien Lin1, and Hsinn-Jyh Tzeng2, Electrical Discharge Machining (EDM) Characteristics Associated with Electrical Discharge Energy on Machining of Cemented Tungsten Carbide, Materials and Manufacturing Processes, 23: 391–399, 2008

[7] Che-ChungWang, Han-Ming Chow, Lieh-Dai Yang, Chun-Te Lu, Recast layer removal after electrical discharge machining via Taguchi analysis: A feasibility study, Journal of Materials Processing Technology 209 (2009) 4134–4140

[8] O. A. Abu Zeid, “On the effect of electro-discharge machining parameters on the fatigue life of AISI D6 tool steel”, Journal of Materials Processing Technology, 68, pp. 27–32, September 1997.

[9] Weller, E.J., 1984. Non traditional Machining Processes, Society of Manufacturing Engineers, 2nd ed. The Society of Manufacturing Engineers, Dearborn, pp. 3–11.

[10] Ho, K.H., Newman, S.T., 2003. State of the art electrical discharge machining (EDM), Int. J. Mach. Tool Manu. 43 (13), 1287–1300.

[11] Naveen Beri, S. Maheshwari, C. Sharma, Anil Kumar, Performance Evaluation of Powder Metallurgy Electrode in Electrical Discharge Machining of AISI D2 Steel Using Taguchi Method

[12] Hassan El-Hofy, Advanced Machining processes, publisher-McGraw-Hill

[13] R.M. Gill, Carbon Fibers in Composite Materials, Ilife Press, London, 1971, p. 1.

[14] G.W. Meetham, High temperature materials—a general review, J. Mater. Sci. 2(1991) 853–860.

[15] E. Fitzer, Future of carbon–carbon composites, Carbon 25 (2) (1987) 163–190.

[16] L.M. Manocha, O.P. Bahl, Y.K. Singh, Fiber matrix interface in carbon–carbon composite—effect of surface morphology of carbon fibers, Carbon 27 (3) (1989) 381–387.

[17] W. Koening, R. Komanduri, H.K. Tokanshoff, Machining of hard metals, Ann. CIRP 33 (2) (1984) 417–427.

[18] R. Snoeys, F. Staelens, W. Dekeseve, Current trends in non-conventional material removal processes, Ann. CIRP 35 (2) (1986) 467–480.

[19] F. Gary, Benedict, Non traditional Manufacturing Processes, Marcel Decker, New York, 1987.

[20] P.M. George , B.K. Raghunath , L.M. Manocha, Ashish M. Warrier , EDM machining of carbon–carbon composite—a Taguchi approach, Journal of Materials Processing Technology 145 (2004) 66–71