Machinability Investigation and Optimization of SS-316 using Graphite Electrode in EDM

P. Pratheep[1] Dr. A. Kumaravadivel[2] Mrs. X. Hyacinth Suganthi[3] Mr. E. Sathish Kumar[4]
[1,2,3,4]Sri Raaja Raajan College of Engineering and Technology, India

Abstract— The aim of this paper is to identify the random error caused by micro EDM discharge machine by variying the machining parameters. The work piece medium is SS 316 having (3mm X 50mm X 50mm) standard diamension. The machining of 7 holes continuously by changing spark timing, current intensity and voltage across the electrode and work piece. Then the work piece is cleaned well to remove the extra burr in it. After taking reading the work piece is compared with master piece or actual given value in EDM machining program. The error from the actual and deviated value is calculated by using the error calculating formula. The positioning errors and hole profile deviation is happen in the work piece. The error machine is informed to the maintenance team to carried out the preventive maintenance. The random error is caused by the stepper motor friction in the Micro-Electrical Discharge Machine.

Key words: SS-316, Graphite Electrode, EDM

I. Introduction

The growing trend to use slim, light and compact mechanical components in automobile, aerospace, medical, missile, and nuclear reactor industries has led to the development of high strength, temperature resistant, and hard materials during last few decades. It is almost impossible to find sufficiently strong and hard tools to machine aforesaid materials at economic cutting speeds. Moreover, machining of complex shapes in these materials with low tolerances and high surface finish by conventional methods is even more troublesome. Hence, there is great demand for new machining technologies to cut these 'difficult-tomachine' materials with ease and precision. Among modern machining processes, electric discharge machining (EDM) has become highly popular in manufacturing industries due to its capability to machine any electrically conductive material into desired shape with required dimensional accuracy irrespective of its mechanical strength. Joseph Priestley, The English physicist, first noted the erosion of metals by electric sparks in 1770. However, Russian scientists B. R. Lazarenko and N. I. Lazarenko, first introduced controlled machining by electric discharges in 1943. Intermittent arcing in air between tool electrode and workpiece material, connected to a DC electric supply, caused the erosion of material. The process was not very accurate due to overheating of the machining region and may be defined as 'arc machining' rather than 'spark machining'. During 1980s, the efficiency of EDM raised extraordinarily with the introduction of numerical control (CNC). Self-regulated and unattended machining from loading the electrodes into the tool changer to a finished smooth cut was possible with CNC control system. Since then, these emergent virtues of EDM have been vigorously sought after by the manufacturing industries producing tremendous economic advantage and creating keen research interest.

II. Principle of EDM

Despite the fact that the material removal mechanism of EDM is not absolutely identified and is still contentious, the most widely established principle is the transformation of electrical energy into thermal energy through a sequence of distinct electric discharges. Fig. 1.1 shows a representative diagram of a typical EDM setup. Build-up of suitable voltage across tool and work-piece (cathode and anode respectively) that are submerged in an insulating dielectric, causes cold emission of electrons from the cathode. These liberated electrons accelerate towards the anode and collide with the dielectric fluid, breaking them into electrons and positive ions. A narrow column of ionized dielectric fluid molecules is established connecting the two electrodes. A spark generates due to the avalanche of electrons. This results in a compression shock wave. Very high temperature (8,000 to 12,000 ºC) is developed which induces melting and evaporation of both the electrodes. The molten metal is evacuated by the mechanical blast (of the bubble), leaving tiny cavities on both tool and work piece.

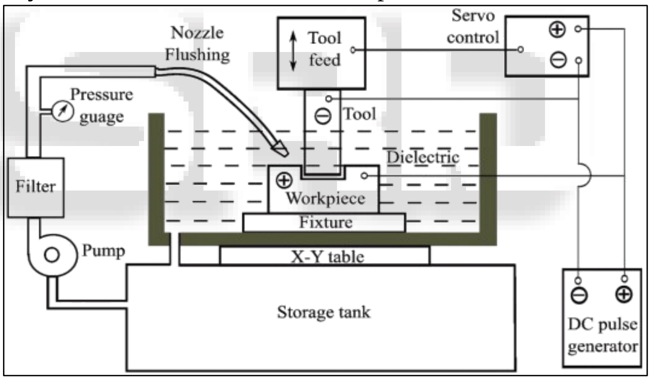


Fig. 1: EDM Machine

III. Performance measure in EDM

Material removal rate (MRR) determines the productivity of any machining process. It can be defined as the volume of the material removed in a unit time. MRR achieved during EDM is quite low (0.1 to 10 mm3/min-A). Actual value of MRR depends on the machining conditions employed. Overcut determines the accuracy of EDM process. It is the difference between the size of the electrode and the size of the cavity created during machining. Overcut has to be minimized to achieve close tolerances on the machined components. Since the material removal in EDM is achieved through the formation of craters due to the sparks, it is obvious that larger crater size results in a rough surface. So, the crater size, which depends mainly on the energy per spark, controls the quality of the surface.

All rights reserved by www.ijsrd.com

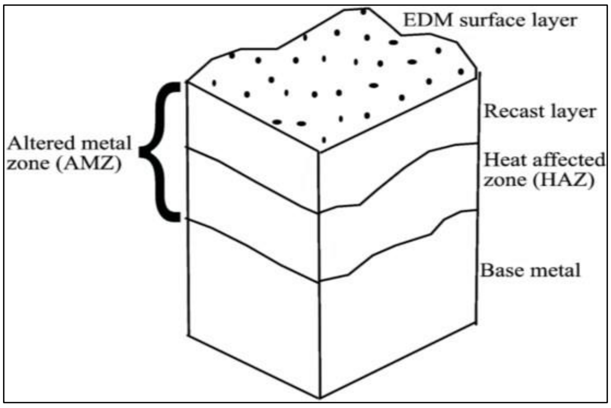


Fig. 2: Layer of an EDM

Apart from productivity (MRR), surface integrity of the machined component plays a vital role in the selection of a machining process. Surface integrity deals basically with two issues, i.e., surface topography and surface metallurgy (possible alterations in the surface layers after machining). Surface integrity greatly affects the performance, life and reliability of the component. Typically EDM results in two kinds of surface or sub-surface layers, i.e., recast layer, heat affected zone (HAZ) as shown in Fig. 1.4. If molten material from the work piece is not flushed out quickly, it will re-solidify and harden due to cooling effect of the dielectric, and gets adhered to the machined surface. This thin layer (about 2.5 to 50 μm) is known as 're-cast layer or white layer'. It is extremely hard and brittle and hence often causes micro cracks to nucleate and proliferate. The layer next to recast layer is called 'heat affected zone'. Heating, cooling and diffused material are responsible for the presence of this zone. Thermal residual stresses, weakening of grain boundary, and consequent formation of cracks are some of the characteristics of this zone. The application of higher discharge energy results in deeper HAZ and subsequently deeper cracks. Excessive local thermal expansion and subsequent contraction may result in residual tensile stresses in the eroded layer. The surface finish achieved during EDM is also influenced by the chosen machining conditions. Surface finish is primarily governed by the pulse frequency and energy per spark.

IV. CATEGORIES OF EDM

EDM facilitates the machining in a number of ways, a lot of these operations are similar to conventional machining operation, for instance milling and die sinking. A variety of classifications are possible and recent developments in its technology append new operations owing to increase in various requirements. A simple and general classification can be given in view of standard applications such as,

A. Die sinking EDM

Die sinking EDM, comprises a tool electrode and work piece that are immersed in an insulating dielectric fluid. A pulsating power supply that produces a voltage potential, connects the tool and work piece. A constant gap between the tool and the work piece is maintained by a servo motor control of the tool holder. As tool moves towards the work piece, dielectric breaks down into electrons and ions, creating a plasma column between two electrodes. A momentary flash jumps between the electrodes. Automatic movement of tool, towards work piece takes place as the spark gap increases due to metal erosion. Thus the process continues without any interruption. As a result, the complementary shape of the tool electrode accurately sinks into the work piece.

B. Electric discharge milling

Electric discharge (ED) milling is an evolution of CNC contouring EDM. A rotating cylindrical electrode follows a programmed path in order to obtain the desired shape of a part, like a cutter used in conventional computerized numerical controlled (CNC) milling. Compared to traditional sinking EDM, the use of simple electrodes in ED milling eliminates the need for customized electrodes. In the ED milling, the simple shape electrode does layer-by-layer milling to get a three-dimensional complex parts, at the same time, electrical discharges occur repeatedly to remove materials along the programmed path. According to the discharge status between the electrode and the work piece, the control system determines the forward and withdrawal feed rate of the electrode.

C. Electric discharge grinding (EDG)

Electric discharge grinding (EDG) is the process which works on the same principle as EDM. A rotating wheel made of electrically conductive material, is used as a tool. A part of the grinding wheel (cathode) and work piece (anode) both are immersed in the dielectric, and are connected to DC power supply. The rotating motion of the wheel ensures effective flow of dielectric in the IEG, and hence flushing the gap with dielectric can be eliminated. Mechanism of material removal is exactly same as in EDM except that rotary motion of the tool helps in effective ejection of the molten material. Contrary to conventional grinding, there is no direct physical contact between the tool and work piece, hence fragile and thin sectioned specimens can be easily machined. EDG is also considered to be economical compared to the conventional diamond grinding.

D. Wire EDM

Wire EDM uses a very thin wire of 0.02 to 0.03 mm diameter usually made of brass or stratified copper as electrode and machines the work piece with electric discharges by moving either the wire or work piece. Erosion of work piece by utilizing spark discharges is very same as die sinking EDM. This process is frequently used to machine plates about 300 mm to manufacture dies, punches, and tools from hard materials which are difficult to machine using other processes.

E. Micro – EDM

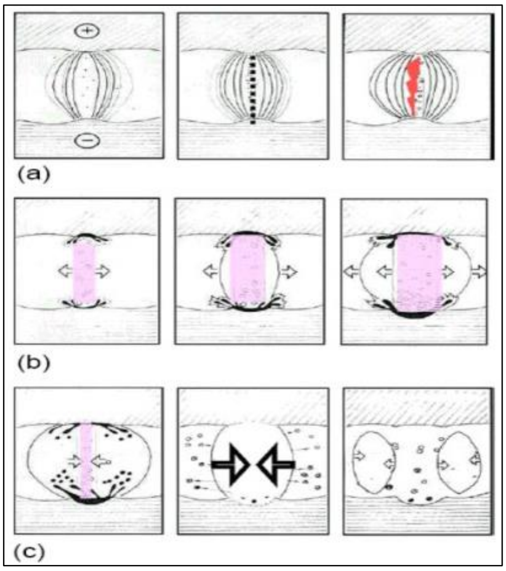
The present trend of miniaturization of mechanical parts has given μ-EDM a considerable research attention. Using this process, it is possible to produce shafts and micro holes diameter as less as 5 μm, and also intricate three dimensional shapes. It is extensively utilized for the fabrication of micro arrays, tool inserts for micro-injection molding, and hot embossing. In the beginning, μEDM was employed mostly for fabricating small holes in metal sheets. Owing to the versatility of the process, currently it is used in the manufacturing of micro molds and dies, tool inserts, micro

All rights reserved by *www.ijsrd.com*

filters, micro fluidic devices, housings for micro-engines, surgical equipment etc.

V. THEORETICAL BACKGROUND

Phase of discharge - The discharge process during EDM can be separated into three main phases .They are preparation phase, discharge phase and interval phase. Details of each phase are discussed below. (a) Preparation phase on switching on the power supply, electric field is set-up in the gap between the electrodes. The electric field reaches maximum value at the point where the gap between the electrodes is smallest. Spark location is determined by the gap distance and the gap conditions. In the presence of electrically conductive particles in the gap, thin particle bridges are formed. When the strength of the electric field exceeds the dielectric strength of the medium, electric breakdown of the medium takes place. Ionization of the particle bridges takes place and a plasma channel is formed in the gap between the electrodes. The steps in the phase are the shown fig.(a). (b).Discharge phase - During the discharge phase (Figure b), a high current flows through the plasma channel and produces high temperature on the electrode surfaces. This creates very high pressure inside the plasma channel creating a shock wave distribution within the dielectric medium. The plasma channel keeps continuously expanding and with it the temperature and current density within the channel decreases. Plasma channel diameter stabilizes when a thermal equilibrium is established between the heat generated and the heat lost to evaporation, electrodes and the dielectric. This enlarged channel is still under high pressure due to evaporation of the liquid dielectric and material from the electrodes. The evaporated material forms a gas bubble surrounding the plasma channel. During this phase, high energy electrons strike the work piece and the positively charged ions strike the tool (for negative tool polarity). Due to low response time of electrons, smaller pulses show higher material removal from the anode where as, longer pulses show higher material removal from the cathode. (c).Interval phase - The plasma channel de-ionizes when power to the electrodes is switched off. The gas bubble collapses and material is ejected out from the surface of the electrodes in the form of vapors and liquid globules. The evaporated electrode material solidifies quickly when it comes in contact with the cold dielectric medium and forms solid debris particles which are flushed away from the discharge gap. Some of the particles stay in the gap and help in forming the particle bridges for the next discharge cycle. Power is switched on again for the next cycle after sufficient de-ionization of dielectric has occurred. The steps in the phase are shown in Figure (c).



(a)Preparation phase (b) Discharge phase (c) Interval phase

VI. PROCESS MECHANISM

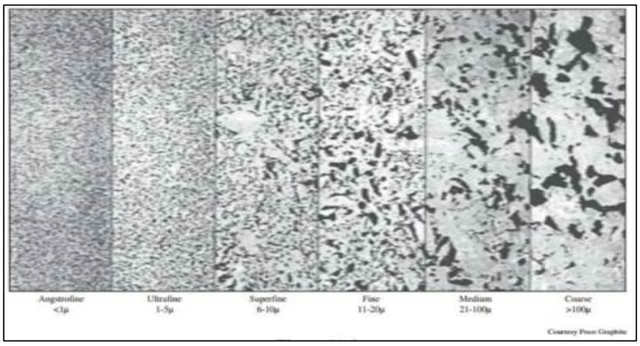
It is not absolutely necessary to understand the operating principles of EDM to be a successful machinist. However, an understanding of what is taking place between the electrode and the work piece can aid the EDM in several important areas. A basic knowledge of EDM theory can help with troubleshooting, in selecting the proper work metal/electrode combinations, and in understanding why what is good for one job is not always good for the next. The following description represents a combination of what is known plus what is theorized about the process. While several theories of how EDM works have been advanced over the years, most of the evidence supports the thermoelectric model. The following nine illustrations show step -by-step what is believed to happen during an EDM cycle. The graphs below the illustrations show the relative values of voltage and current at the point depicted.

VII. GRAPHITE ELECTRODE MATERIAL

Graphite is the most commonly used material for electrode. Graphite was introduced in EDM industry around 50 years ago. General Electric was the first, well known manufacturer to introduce graphite in EDM industry. It was known by its trade name "Gentrode". Unlike other metal based electrode material, graphite has certain unique properties which keep it above others as a suitable material for EDM electrode. Its heat resistivity is thousands of degrees higher than other materials. It does not melt like other materials; instead it turns straight into gas from solid state. This is also a disadvantage because, instead of creating chips and staying under the di-electric, it causes a dusty cloud to form in work place. This is hazardous if not followed precaution. Vacuuming the dust is a good idea to prevent from breathing graphite in while at work place. Graphite, despite being the best option as an electrode material, has some limitations in molecular level. It is porous so when immerged in di-electric fluid it can cause problematic impurities. Trapped moisture can create steam when cutting which damages the electrode. Due to this problem, it is better to use denser at graphite which shows

All rights reserved by *www.ijsrd.com*

little penetration even after long hours of soaking. One other way of using graphite without facing problem is to heat the electrode in oven for an hour 121°C.



A. *Graphite Grades*

Grain size and density defines the quality of graphite as an electrode. It also determines its price and cutting efficiency. Graphite with finer grain size results on better finishing and wear resistance, but graphite with larger grin size costs less.

1) Sub-Micron:
This grade of graphite is the most expensive one and has the grain size of less than one micron i.e. Angstrofine graphite.

2) Premium:
Graphite with less than or equal to 5 microns, i.e. Ultrafine, falls under premium grade of Graphite.

3) High performance:
Superfine to fine Graphite with 10-20 microns size is high performance Graphite.

4) General purpose:
Graphite with grain size of larger than 20 microns are general purpose Graphite.

VIII. CHEMICAL PROPERTIES

Mateial	C%	Si%	Cr %	S%	P%	M %	N%
SS-316	0.08	0.75	12	0.03	0.045	2	0.10

IX. PHYSICAL PROPERTIES

Density, 0.29 Ibs/in3 7.99g/cm

X. IMPORTANT PARAMETERS OF EDM

A. *Spark on time (Pulse on time or Ton)*

The duration of time the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on- time. The energy is really controlled by the peak current and the length of the time.

B. *Spark off time (Pulse off time or Toff)*

The duration of time between the sparks (that is to say, on time). This time allows the molten material to solidify and to be wash out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off-time is too short, it will causes sparks to be unstable.

C. *Arc off the gap*

The Arc gap is distance between the electrode and work piece during the process of EDM. It may be called as spark gap.

D. *Discharge current (Ip)*

Current is measured in amp allowed to paper cycle. Discharge current is proportional to the to the material removal rate.

E. *Duty cycle*

It is a percentage of the on time relative to the total cycle time. This parameter is calculated by dividing the on-time by the total cycle time.

F. *Voltage (V)*

It is a potential that can be measure by volt it is also effect to the material removal rate and allowed to per cycle. Voltage is given by in this experiment is 50 V.

G. *Dia. of electrode (D)*

It is the electrode of Cu-tube there are two different size of diameter 4mm and 6mm in this experiment. This tool is used not only as an electrode but also for internal flushing.

H. *Over cut*

It is a clearance per side between the electrode and the work piece after the marching operation.

XI. VIDEO MEASURING SYSTEM

Video coordinate measurement machines are specifically designed for noncontact measurement and inspection of small intricate features on small or large parts. These video measurement systems are a natural step up from measuring microscopes and optical comparators. With granite base construction and steel stages the system provide long term accuracy and reliability, an excellent ROI. Video measuring systems may be configured with measurement software or metrology specific DROs. The fully self-contained XT-2000 VNP is an efficient compact floor standing model again featuring all granite structure and steel stage. As well the system is ergonomically designed with stage positioning, lighting and Z axis focusing right of the operator. Advanced intuitive edge detection software makes part measurement and easy to learn quick process. Science scope measurement software is very easy to use, not requiring a dedicated specially trained operator. Type of video measurement system are Manual video measurement system, CNC type video measurement system.

XII. EDM OF SS-316 BY GIVEN PARAMETER

Holes	1	2	3	4	5	6	7
Dia(mm)	0.6	0.6	0.6	0.6	0.6	0.6	0.6
X-axis(mm)	0.0	8.0	16.0	24.0	32.0	32.0	32.0
Y-axis(mm)	0.0	0.0	0.0	0.0	0.0	15.0	30.0
Ton(s)	2	3	4	3	2	3	3
Toff(s)	3	2	3	2	2	2	4
Ib	2	3	3	2	3	4	3
Sv	4	4	4	4	4	3	2
Time	1.06	1.05	1.03	38	32	38	31

All rights reserved by *www.ijsrd.com*

Voltage	40	40	40	40	40	40	40

XIII. Error Analysis

No measurement of a physical quantity can be entirely accurate. It is important to know, therefore just how mach the measured value is likely to deviated from the unknown, true value of the quantity. The art of estimating these deviation should probably be called uncertainty analysis, but for historical reasons is referred to as error analysis. This document contains brief discussions about how errors are reported, the kins of errors that can occur, how to estimate random errors, and how to carry error estimates into calculated results. We are not, and will not be concerned with the "percent error" exercises common in high school, where the student is content with calculating the deviation from some allegedly authoritative number.

XIV. Estimation Random Error

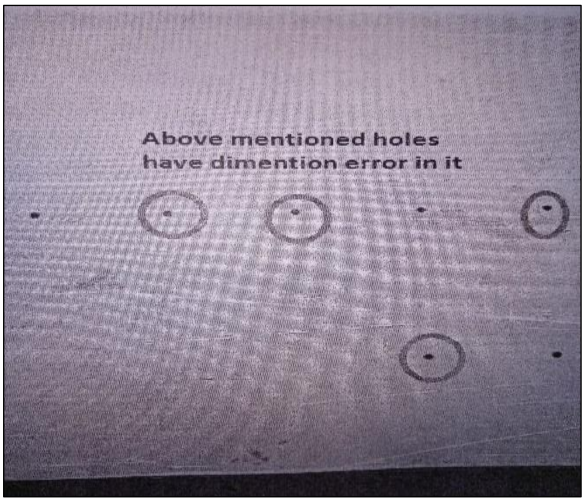
There are several ways to make a reasonable estimate of the random error in a in a particular measurement. The best way is to make a series of measurement of a given quantity and calculate the mean x, and the standard deviation from this data. The mean is defind as

$$\% \text{ Error} = \left| \frac{\text{measured} - \text{accepted}}{\text{accepted}} \right| \times 100$$

XV. Error Showing Tabulation

Holes	Dia	Actual value		Measured value		% Error	
		X axis	Y axis	X axis		X axis	Y axis
1	0.06	0.0	0.0	0.0	0.0	0.0%	0.0%
2	0.06	8.0	0.0	8.01	0.0	0.125%	0%
3	0.06	16	0.0	16.02	0.0	0.125%	0%
4	0.06	24	0.0	24	0.0	0%	0%
5	0.6	32	0.0	32.01	0.0	0.03%	0%
6	0.6	32	15	32.0	15	0.%	0%
7	0.6	32	30	32.01	30	0.03%	0%

XVI. Error Identification



XVII. Conclusion

Thus I am identify the random error caused by micro EDM discharge machine by varying the machining parameters. The work piece medium is SS 316 having (3mm X 50mm X 50mm) standard dimension. The machining of 7 holes continuously by changing spark timing, current intensity and voltage across the electrode and work piece. Then the work piece is cleaned well to remove the extra burr in it. The finished work piece is measured by non-conducting video measuring device namely video measuring system. It is high accurate holes profile measuring device by using the optical light. After taking reading the work piece is compared with master piece or actual value given value in EDM machine. The error from the actual and deviated value is calculated by using the formula. The error of machine is informed to the maintenance team to carry out the preventive maintenance. The random error is caused by the stepper motor friction in the Micro EDM.

References

[1] J.Simno, H.G. Lee, D.K. Aspinwall, R.C.Dewas, and E.M. Aspinwall 2003. Workpiece modification using electrical discharge machining, 43 (2003).
[2] Lee,S.H., and Li, X.P., 2001. Study of the effect of machining parameters on the machining characterstics in EDM of tungsten carbide. Journel of material processing technology,115(3), 344-358.
[3] Y.H.Guu, AFM surface imaging of AISI D2 tool steel machined by the EDM process applied surface science 242 (2005) 245- 250.
[4] P.Balasubramanian, T. Senthilvelan Optimization of machining parameters in EDM process using cast and sintered copper electode procedia material science 6 (2014) 1292-1303.
[5] Vikasa, Apurba kumar Royb, Kausik kumar Effect and Optimization of Various Machine Process on the Surface roughness in EDM for an EN41 Material using Grey Taguchi Precidia Materials science 6 (2014) 383-390.

All rights reserved by *www.ijsrd.com*