Development and Experimental Investigation of Dry Electric Discharge Machining Process (EDM Process)

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Abstract - *An Electric discharge machining (EDM) is one of the most popular non-traditional machining processes used. Generally, EDM uses oil based dielectric medium but that dielectric medium causes few environmental issues like pollution, fire hazards and recycling of used oil is not possible. Dry EDM process can be used to overcome these drawbacks by passing high velocity gases through tool electrode. In dry EDM oxygen, nitrogen, helium, compressed air can be used as dielectric medium, thus making oil based EDM environment-friendly. The prime objective of project will be to study drilling operation of mild steel using dry EDM process and to investigate its machining properties experimentally. This work involves drilling of mild steel using different process parameters by dry EDM in order to measure material removal rate, tool wear rate and surface roughness.*

Key Words: Dry EDM, MRR, Tool Wear Rate, Surface Roughness

1. INTRODUCTION

This Electrical Discharge Machining (EDM) process is one of the widely used processes to machine electrically conductive materials. EDM is a thermo-electric process in which material removal takes place through the process of controlled spark generation. It is one of the most popular non-traditional machining processes being used today in the industry. EDM is commonly used in mould making industries, die making industries, manufacturing automotive, aerospace and surgical components. Thin and delicate components can be machined without the risk of damage because there is no mechanical contact between the tool and the workpiece which is to be machined.

EDM has the ability to machine any electrically conductive material irrespective of its mechanical strength. Therefore, EDM has achieved a very important status in the industry. But in spite of its so many advantages, the environmental issues associated with the process have been a major drawback of EDM. The dielectric fluid used in EDM is the primary source of pollution from the process. Hydrocarbon based oils are the most commonly used in EDM process. Dielectric wastes generated after machining are very toxic and cannot be recycled. Also, toxic fumes are generated due to high temperature chemical breakdown of dielectric during machining. The use of oil as the dielectric fluid necessitates extra care for prevention of fire hazards. The environment friendly alternative for replacing the EDM process is dry EDM process. In case of EDM process the dielectric fluid used is in the form of liquid (oil based) whereas in case of dry electric discharge machining (dry EDM) this liquid dielectric is replaced by a gaseous dielectric. In dry EDM process high velocity gas flowing through the tool electrode into the inter-electrode gap substitutes the liquid dielectric. This flow of high velocity gas also helps in the removal of debris and prevents excessive heating of the tool and workpiece at the discharge spots.[7]

2. LITERATURE REVIEW

In 1996 the feasibility of using air as the dielectric medium was first demonstrated by Kunieda and Yoshida [1]. They have used steel as workpiece, copper as tool electrode and compressed air as dielectric. They found that material removal rate was doubled with use of oxygen gas as dielectric. They conclude that the material removal rate is improved as the concentration of oxygen in air is increased due to heat generation caused by oxidation of the electrode materials.

Kunieda et al. [2] have used a piezoelectric actuator to improve the dry EDM characteristics by controlling the discharge gap distance. They have used copper as tool electrode, carbon steel as workpiece and compressed air as dielectric. They found that with increasing gain of the driver for the piezoelectric actuator, the probability of short circuiting decreases, resulting in considerable increase of the material removal rate.

Kunieda and Furudate [3] have worked on high precision finish cutting by dry WEDM in 2001. In their experiment, they worked on flat surface of carbon steel or tool steel was finish-cut by conventional and dry-WEDM. They conclude that MRR of dry WEDM is considerably lower than that of conventional WEDM and this is because of frequent occurrence of short circuiting due to narrower gap length in dry WEDM causes unfavorable repetition of the turning back and forth of the wire electrode in the feed direction. From their experiments it was also found that increasing the wire winding speed and decreasing the depth of cut could lead to an improvement in MRR and waviness.

Zhang et al. [4] have investigated on ultrasonic assisted electrical discharge machining in gas in 2006. The experiments were conducted on steel and copper used as tool electrode. They concluded that MRR increases when electrode becomes thinner than diameter of discharge crater and also increases with increase of amplitude of vibration.

Tao et al. [5] have experimentally investigated the dry and near dry EDM process in 2008. A two phase gas-liquid mixture was used as the dielectric medium in near dry EDM. The effect of discharge current, pulse-duration, pulse interval, gap voltage and open circuit voltage was investigated at constant values of gas pressure and tool rpm by using a 2^{5-1} fractional factorial designed experiment. It was found that copper tool and oxygen gas dielectric with a high current and low pulse off time were suitable for rough machining with a high MRR. The highest MRR of 1.8 mm^3 /min have been reported using kerosene-air mixture used as dielectric.

Joshi et al. [6] have worked on experimental characterization of dry EDM performed in a pulsating magnetic field in which stainless steel as workpiece, copper as tool electrode and oxygen gas as a dielectric medium. They have compared dry EDM without magnetic field and dry EDM with magnetic field. They conclude about MRR based on the comparison of two above mentioned machines. They proposed that the increase in MRR due to the use of magnetic field, because the magnetic force acts tangential to the plasma and prevents its expansion.

3. EXPERIMENTAL WORK

The current work aims to develop a unit implementing the dry EDM process on an existing oil based EDM machine. The Figure 3.1 shows photograph of Sumedha S20S EDM. The machine has provision to vary three parameters – current, pulse on time and duty cycle. Table 3.1 gives information of machine parameters and their levels of oil based EDM.

Table 3.1: EDM Machine Parameters and Their Levels

Process Parameters	Levels
Current (amp)	1 to 20
Pulse on time (µs)	2,5,10,30,50,100,200,500
Duty cycle (%)	90,85,80,75,70,65,60,50

The experimental setup consists of oil based EDM, oxygen cylinder, oxygen cylinder regulator, valve, tool holder, electrodes etc.

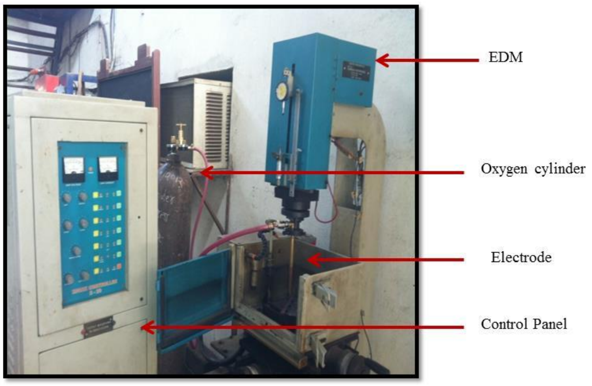


Figure 3.1: Photograph of S20S EDM Machine

The oxygen gas has passed through collar via hose to the hollow electrode and gas is blown on the workpiece. The blown gas is used as dielectric medium in the machining process. The pressure of the gas can be varied using oxygen cylinder regulator. The hollow electrode is fitted to tool holder with connector. A hollow copper pipe is located at the place of solid electrode as in case of oil based EDM with the help of Allen screw. The oxygen gas is blown from hollow electrode towards workpiece under maintained pressure by operator. The pressured oxygen gas is used as dielectric medium.

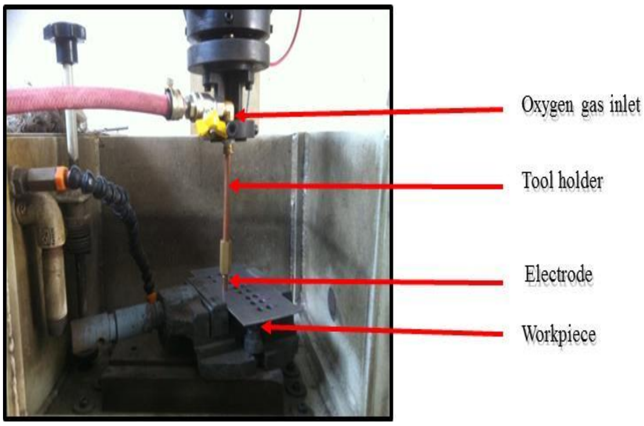


Figure 3.2: Experimental Setup of Dry EDM

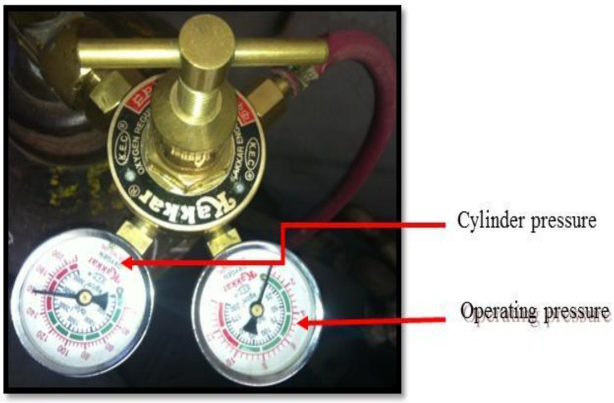


Figure3.3: Photograph of Oxygen Gas Cylinder Regulator

3.1 Experimentation

The details regarding the electrode material and workpiece materials for experiments are given below. The experiments are conducted on mild steel by varying current, pulse on time and oxygen gas pressure. All experiments are conducted at constant duty cycle.

Workpiece material	:Mild Steel
Tool	: Copper
Dielectric	: Oxygen gas
Design of Experiments	: Taguchi method

The experiments conducted by changing following parameters

- Current (amp)

- Pulse on time (µs)
- Dielectric pressure (bar)

3. EXPERIMENTAL RESULTS

As discussed in experimentation, experiments are performed on mild steel as a workpiece and copper as an electrode material. Material Removal Rate, Tool Wear Rate and Surface Roughness are measured as follows

$$MRR\left(\frac{gm}{min}\right) = \frac{Wwb\ (gms) - Wwa\ (gms)}{t\ (min)} \quad ...1$$

$$TWR\left(\frac{gm}{min}\right) = \frac{Wtb\ (gms) - Wta\ (gms)}{t\ (min)} \quad ...2$$

The SR (µm Ra) is measured using Taylor Hobson precision machine.
Where,
W_{wb}= weight of workpiece before machining
W_{wa} = weight of workpiece after machining
W_{tb}= weight of tool before machining
W_{ta} = weight of tool after machining
t = time required for machining
Figure 4.1 shows photograph of the machining (drilling) of mild steel plate of 2mm thick by using dry EDM process. The drills are arranged and numbering is given to them.

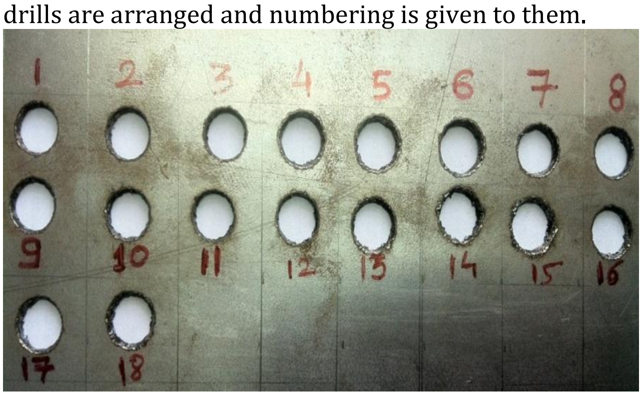
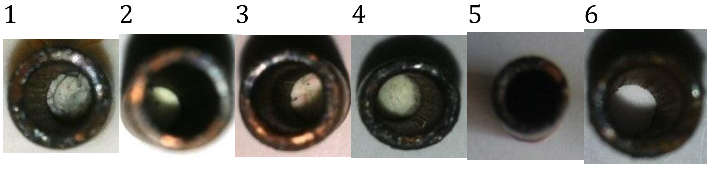


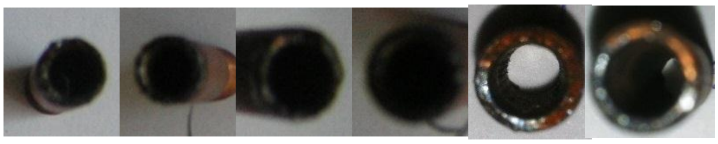
Figure 4.1: Photograph of Drills by Dry EDM

The collection of electrodes after dry EDM is shown in Figure 4.2. These pieces help to study surface of electrode and by observation it can be said that higher wear of electrode occurs at higher current.

1 2 3 4 5 6



7 8 9 10 11 12



13 14 15 16 17 18

Figure 4.2: Photograph of Collection of Electrodes after Dry EDM Process

From the above experiments and discussed methodology response variables are calculated by varying process parameters and results are obtained for each drill.
Experimental results for Material Removal Rate (MRR), Tool Wear Rate (TWR) and Surface Roughness (SR) by varying current, pulse on time and dielectric pressure are shown in Table 4.1.

Table 4.1: Experimental Results

Expt. No.	Process parameters			Response variables		
	Current (amp)	Pulse on Time (µs)	Pressure (bar)	MRR (gm/min)	TWR (gm/min)	SR (µmRa)
1	15	50	1	0.0392	0.0000	3.2
2	15	50	1.5	0.0205	0.0000	4.2
3	15	50	2	0.0270	0.0000	3.6
4	15	100	1	0.0588	0.0000	4.6
5	15	100	1.5	0.0632	0.0000	4
6	15	100	2	0.0698	0.0000	3.6
7	15	200	1	0.0542	-0.0005	4.6
8	15	200	1.5	0.0623	-0.0011	3.6
9	15	200	2	0.0231	-0.0017	3.8
10	16	50	1	0.0484	0.0012	4.6
11	16	50	1.5	0.0335	0.0011	4.8
12	16	50	2	0.0718	0.0012	5.2
13	16	100	1	0.0757	0.0013	3.8
14	16	100	1.5	0.1080	0.0022	4.4
15	16	100	2	0.1092	0.0022	4.6
16	16	200	1	0.0249	0.0000	4.2
17	16	200	1.5	0.0209	0.0000	4.4
18	16	200	2	0.0408	0.0000	4.4

3. CONCLUSION

1 In case of tool wear rate, it is found that TWR is less in dry EDM process. Increasing current and pulse on time increases TWR because an increasing current and pulse on time the pulse energy increases thus more heat energy is produced in electrode interface which leads to melting and evaporation of electrode.

2 It is found that current is significant parameter which influences surface roughness. Current is energy related parameter which creates larger

crater in workpiece increasing surface roughness of machined workpiece.

3 Optimum processing condition for maximizing MRR corresponds to 15th experimental run (16 amp, 100 μs, 2 bar). Optimum processing condition for minimizations of TWR corresponds to 9th experimental run (15 amp, 200 μs, 2 bar).Optimum processing condition for minimization of SR corresponds to 1st experimental run (15 amp, 50 μs, 1 bar).

4 Dielectric pressure does not affect for any response variable in our experimentation.

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