Online Monitoring of Electric Discharge Deposition Process

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***Abstract*—The need for miniature parts is increasing day by day. This growing demand for micro parts has led to the development of many processes for their production, which can be broadly classified as Microlithography, Micro deposition and Material removal (on micro scale). There are various methods in which micro deposition is being carried out. One of the emerging processes in this category is the electric discharge deposition process for the fabrication of micro sized parts. In this process micro tool in the form of wire is used and its wear is increased intentionally so that the worn out material get deposited due to the applied potential voltage. Experiments were conducted to identify the key of operating parameters and their operating ranges and the effect of voltage, current, duty cycle and pulse on time on the deposited weight, height, and width and tool wear length using the centre rotatable composite design of experiment as statistical tool. After this most significant parameters is analyzed as current, duty cycle and pulse on time. The effects of these parameters are analyzed on the multi layer deposition process using a full factorial design.**

***Index Terms*—Micro deposition, EDM**

I. INTRODUCTION

The macro scale parts are manufactured individually and assembled to get the final desired product. But the micro level parts are produced using different methods with layering and bonding being the primary methods of assembly. This growing demand of micro parts has led to the development of many major processes for the production of miniature parts. Some of them are microlithography, micro deposition, and etching. Most of the micro fabrication technologies use the layered manufacturing technologies which are characterized by layer-by-layer build up of parts. Due to layer-by-layer building approach, it is possible to create more complex parts in one set up which is not possible otherwise [1]. The deposition of micro parts requires the ability to move the micro particles and fuse them with a suitable source of energy. Most of the fabrication processes in general utilize metals or metallic powder for fabrication. Non-conventional process such as Electric Discharge Machining (EDM) is being widely used in the industries for machining and is to a great extent used for surface modification of finished parts to impart desired to the exposed surface. This process with slight variation has been evolving as potential process for micro fabrication.

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II. ELECTRIC DISCHARGE MACHINING

The prime requirement for this process is that the Tool and the Work piece must be electrically conductive. This process is thermal in nature with material removal occurring via the discharge of energy between a tool(cathode) and work piece(anode) which are separated by a small gap(~ 5 - 100μm) depending upon the electrical parameters [2]. The entire process generally takes place in a dielectric medium typically hydrocarbon oil or de-ionized water. Literally thousands of electrical discharge circuit and each electrical discharge produces a tiny crater by melting and vaporization of the electrodes. A series of discharge causes the shape reproduction of the tool onto the work piece. The dielectric fluid surrounding the electrodes flushes out the chips and confines the discharges. With this process material of any hardness can be cut as long as the material is electrically conductive [3].

The dielectric fluid surrounding the electrodes is important in electric discharge machining. In the initial stages (until the spark discharge occurs), the dielectric fluid acts as an insulator between the electrodes, permitting the charge to be accumulated in the condenser of the relaxation pulse generator. Ionization of the dielectric fluid begins when the externally applied voltage crosses the breakdown voltage. This breakdown occurs at some small value of spark gap. Electrons then flow from one electrode to another, colliding with the molecules of the dielectric fluid and liberating more electrons, until a narrow plasma channel is formed. This stream of electrons strikes the surface of the work; intense heat on a microscopically small area is produced and this causes the work material to melt and vaporize. The duration of the whole process is a few microsecond. The dielectric fluid helps in concentrating the spark discharge into a narrow channel; this increases the erosive effect. When the spark discharge is complete, the dielectric fluid must de-ionize quickly in order to become an insulating medium for the next discharge.

For Micro Electric Discharge Machining even if tungsten is used as a tool electrode which is one of the materials having lower machinability by the thermal erosion processes the ratio of electrode wear to work piece removal is more than 10%. It is found that smaller is the tool electrode higher is the electrode wear ratio. The conclusion that can be made by this phenomenon is that if proper machining conditions are used there is a possibility to enhance the tool wear rate and material may get deposited onto the work piece [4].

The roughness of the surface machined by negative polarity is coarser than that machined by positive polarity [5]. It has been found that a greater percentage of the supplied energy is dissipated at the anode; the typical value is about 45% at the anode 25% at the cathode. [6].This implies that if the tool is connected to the positive terminal (as the anode i.e. reverse polarity) then the process would aid in rapid wear of tool electrode. This phenomenon can be aid in the deposition of tool material on to the work piece surface. For aluminum, use of inert gasses such as nitrogen and argon as dielectric would aid in better deposition process [7]. Use of inert gas medium reduces the material loss due to oxidation so the rate of deposition increases in these medium. Gases are insulators and have a less breakdown voltage (3kV/mm) and compared to liquid dielectric (10kV/mm). Gases recover immediately after the discharge for the next discharge to occur thereby preventing the chances of arcing. This property is also helpful in generating ultra small discharges thereby increasing the uniformity of the deposited layer [8].

The objective of the paper is to study the effect of EDM process parameters (voltage, current, duty cycle, and pulse on time) on the characteristics of deposited materials physical properties (weight, height, width). In this study, experiments need to be conducted to study the effects of various process parameters on the characteristics of the deposited material. After every set of experiments a regression equation need to be developed to know the effects of input parameters on the output parameters.

III. Experimental Setup

The Electric Discharge Deposition Process is carried out on a NC – EDM machine (as shown in Fig 1) with reverse polarity and air as dielectric. The EDM machine is a Z Axis numerically controlled machine with manual table feed.

The Control panel of the machine has a provision to set independent voltage, current, pulse on- time and duty cycle for the machining process. It has a provision for setting the arcing sensitivity and anti-arcing sensitivity. The time for machining can be set in it with a provision for auto flushing (the time for auto flushing can be set depending on the depth to be flushed). In order to conduct the electro discharge deposition experiments automated table travel is necessary. To facilitate this feature the table was made in such a way that table movement is controlled by the use of two stepper motor, driver circuits through Lab-VIEW software.

Fig. 1. Experimental setup

There is an arrangement made in the machine table of X and Y direction motion by the use of stepper motors. The motors are driven by a control circuit which gets input signals from the computer. Power supply for the motors as well as the control circuit board is given via a regulated power supply. The value of voltage for the motors is 6v and that for the control circuit drive board is 5V. The control circuit board through its logic signal processing by the use of integrated chips generates the necessary signals for the four coils of the stepper motor in logical sequence in accordance with the specified direction.

As the motor rotate the table gets its linear motion. The head of the machine is stationary and therefore the relative motion between the tool and work-piece is achieved.

The stepper motor is controlled by using a lab view programme giving logical supply to NI ELVIS kit. As stepper motor operates at 6V supply voltage and NI ELVIS kit at 5V supply, required control circuit formed. In control circuit we used 4 Tip122 IC for each axis control.

This stepper motor RS 191-8384 contains 8 wires RED, YELLOW, BLUE, GREEN, RED-WHITE, YELLOW-WHITE, BLUE-WHITE, GREEN-WHITE. We made all combination of colour-white ground. We made logic sequenced of pulses for completion of one complete cycle as specified.

IV. Parametric Analysis

After calculating the operating parameters in accordance with the coded variables as per DOE, the various combination of the input parameters are taken for experiments and the responses measured are shown below in Table1. The complicated shapes were fabricated through this process as shown in Fig. 2 and Fig3.

Fig. 2. Showing fabricated Hexagonal micro structure

Fig. 3. Showing fabricated star shape micro structure

It is observed that the deposited weight increases with an increase in duty cycle. The energy generated per cycle is equal to product of voltage, current and duty cycle. As duty cycle increase the energy pulse cycle increases as well as the pulse off time decreases due to which he heat generated in the sparking zone has lesser time to dissipate.

TABLE 1: INPUT PARAMETERS AND MEASURED RESPONSES

	Input parameters				Responses		
No	Voltage (volt)	Current (amperes)	Duty cycle (%)	Pulse on time (μsec)	Weight (milligram)	Width (μm)	Wire wear (mm)
1	60	6	40	10	1.3	287	4.64
2	80	6	40	10	1.1	305	3.57
3	60	8	40	10	1.7	305	7.2
4	80	8	40	10	1.4	324	5.59
5	60	6	72	10	1.7	313	7.75
6	80	6	72	10	1.3	331	6.04
7	60	8	72	10	2.4	349	8.8
8	80	8	72	10	2	354	7.06
9	60	6	40	30	1.8	314	7.59
10	80	6	40	30	1.5	324	5.11
11	60	8	40	30	2.5	333	7.61
12	80	8	40	30	2.1	342	5.95
13	60	6	72	30	2.3	349	8.82
14	80	6	72	30	1.9	359	6.42
15	60	8	72	30	3	376	10.86
16	80	8	72	30	2.5	401	7.79
17	50	7	56	20	1.9	284	7.34
18	90	7	56	20	1.4	358	5.95
19	70	5	56	20	0.9	276	4.44
20	70	9	56	20	2.5	394	9.71
21	70	7	24	20	0.7	273	2.94
22	70	7	88	20	2.4	366	7.91
23	70	7	56	5	0.8	266	2.46
24	70	7	56	50	2.3	364	9.22
25	70	7	56	20	1.8	339	6.96
26	70	7	56	20	1.8	337	6.84
27	70	7	56	20	1.9	339	6.92
28	70	7	56	20	1.8	343	7.02
29	70	7	56	20	1.9	339	7.09
30	70	7	56	20	2	334	7.11

V. CONCLUSIONS

By using EDM, deposition can be achieved and its showing positive trend to fabricate mini products in terms of nano and micro scale.

The study of the Electric Discharge Deposition process for fabrication of micro structure is done. The process variation is studied for the deposition of Single layer and Multi layer. From the experimental results, the following conclusions were made:

1) The deposition weight and height increases with increasing current, duty cycle and pulse on time but decreases with increase voltage. However the deposited width increases with increase in current, duty cycle, and pulse on time and voltage.
2) Current, duty cycle and pulse on time have been found as the most significantly contributing factors in the deposition process. Voltage is found to have less contribution in the deposition process.
3) The multi layered deposition process also shows the same trend as followed by single layer deposition process.

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