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Research Article

Study of Surface integrity Characteristics on Al and Die Steel Components using Copper tool in Sink EDM Process

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Abstract

Electrical discharge machining is considered as one of the main non-conventional machining processes used for manufacturing geometrically complex or hard material parts that are extremely difficult to machine by conventional machining processes. The process involves a controlled erosion of electrically conductive materials by the initiation of rapid and repetitive spark discharges between the tool and work piece in the presence of dielectric medium. The most important process parameters in EDM are material removal rate, electrode wear and surface roughness. The present work is focused to obtain a comprehensive study of surface roughness parameters (Ra, Rz, Rzmax & Rsm) of work materials at different currents in sink EDM process. The experiments were carried out on Al & Die steel components at different currents using cu as a common tool material. The surface roughness parameters under study included average roughness (Ra), average maximum height of the profile (Rz), maximum roughness depth (Rzmax) and the mean spacing of the asperities (Rsm). Machining time of each component and micro hardness of the work pieces before and after machining ware also obtained. In this work the Surface integrity was characterized by roughness parameters and micro hardness values. The results of this investigation revealed that the surface roughness parameters, machining time and micro hardness of work pieces were influenced by current and could be utilized to achieve desired quality of surface finishing thereby increasing the EDM efficiency.

Keywords: *EDM, Micro hardness, Machining time, Surface integrity, Surface roughness parameters.*

1. Introduction

The history of EDM techniques goes as far back as the 1970's when it was discovered by English scientist Joseph priestly. He noticed in his experiments that electrical discharges had removed material from the electrodes. Although it was originally observed by priestly, EDM was imprecise and riddled with failures. In 1943, soviet scientists announced the construction of the first spark erosion machining. The spark generator used in 1943, known as the Lazarenko circuit, has been employed for several years in power supply for EDM machines and an improved form is used in many applications. Commercially developed EDM techniques were transferred to a machine tool. This migration made EDM more widely available and a more appealing choice over traditional machining processes. Two kinds of research trends are carried out by the researchers viz. modeling technique and novel technique. Model technique includes mathematical modeling, artificial intelligence and optimization techniques such as regression analysis, artificial neural network, genetic algorithm etc. The modeling techniques are used to validate the efforts of input parameters on output parameters (Kumar sandeep, 2013). The main machining output parameters in EDM are material removal rate (MRR), tool wear ratio (TWR) and surface roughness. Novel techniques deal with other machining principles either conventional or unconventional such as ultrasonic can be incorporated into EDM to improve efficiency of machining processes to get better material removal rate and surface quality. Surface integrity deals with two issues, e.g. surface topography and surface metallurgy (i.e. possible alterations in the surface layers after machining). Surface integrity greatly affects the performance, life and reliability of the component.

As shown in the fig.1, the EDM surface is made up of three distinctive layers consisting of recast layer/white layer, heat affected zone and unaffected parent metal (Ho and Newman, 2003). Since the recast layer is the topmost layer exposed to the environment, it exerts a great influence on the surface properties of the work piece. This layer is formed by the un-expelled molten metal solidifying in the crater. The molten metal is rapidly quenched by the dielectric (Asif Iqbal and Ahsan Ali Khan, 2010). The EDM process systematically induces an increase in the hardness of the outer layer of machined surfaces. The increase in rate also depends on the type of machined material (Ghanem, et al, 2003).

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The discharge energy *W* for EDM is defined as:

$$W=\int U(Ti)I(Ti)dTi \quad (1)$$

Where *W* denotes the discharge energy (J), *U* represents the discharge voltage (V), *I* is the peak current (A) and *Ti* the pulse-on duration (microseconds).

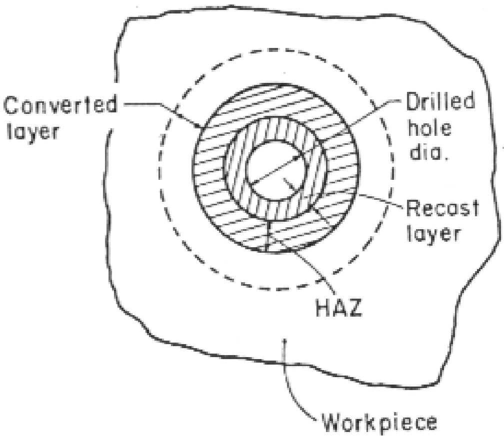

Fig.1 Schematic diagram of three kinds of layers EDM' on EDM'd component

There have been published studies continuing surface finish of machined materials by EDM. It was noticed that various machining parameters influenced the material removal rate, tool wear ratio and surface roughness and by setting possible combination of these parameters optimum surface quality, material removal rate and tool wear ratio was obtained. The machining parameters which influence surface roughness parameters are pulsed current, pulse time, pulse pause time, voltage, dielectric liquid pressure and electrode material. The present work is focused on study of surface roughness parameters (Average roughness (Ra), Average maximum height of the profile (Rz), Maximum roughness depth (Rzmax) and the mean spacing of the asperities (Rsm)) and Micro hardness of Al and Die-Steel Components in sink EDM process.

2. Experimental Set-Up and Procedure

2.1 Machine tool

The experimental setup consists of CR-6C Creator (SYCNC PC-60) Sink type Electro Discharge Machine, Taiwan (shown in fig. 2). It is energized by a 50A pulse generator. Ruslic oil was used as a dielectric fluid during the experiments.

The surface roughness parameters were measured by Handy surf E-354 Surface testing analyzer, model EMC-S24B.

The micro hardness was measured by micro hardness tester FM-300e.

2.2 Work piece material

The work piece materials in this work were Al and Die steel, having the properties shown in Table.1

Table 1: Work piece material properties

Material	Al	Die-Steel
Density(g/cm^3)	2.70	7.7-8.0
Thermal conductivity (W/m K)	237	19.9-48.3
Electrical resistivity (Ω.m)	2.65x10^{-8}	7.2x10^{-7}
Coefficient of thermal expansion (x 10^{-6} ^{0}C^{-1})	23.1	9.5-15.1
Melting point (^{o} C)	660	1435

2.3 Electrode material

Electrode material considered for analysis was copper and its properties being shown in Table.2

Table 2: Electrode material properties (copper)

Material	cu
Density(g/cm^3)	8.9
Thermal conductivity (W/m K)	268-389
Electrical resistivity (Ω.m)	1.72x10^{-8}
Coefficient of thermal expansion (x 10^{-6} ^{0}C^{-1})	6.6
Melting point (^{o} C)	1083

2.4 Experimental Procedure

The Experimental work was carried out on CR-6C Creator (SYCNC PC-60) Sink type Electro Discharge Machine using ruslic oil as a dielectric fluid. The experiments on Die steel and Al samples which were in the form of cylindrical shapes of diameter 50mm each were carried out using different machining setting's with Copper electrode. Cylindrical copper tool's with a diameter of 12mm each ware used as electrodes for machining both Al and die steel work pieces. The copper electrodes ware finished ground before experimental study.

Fig. 2 Sink type Electro Discharge Machine

Three work pieces of each Aluminum and Die Steel were used and machined on EDM using separate copper electrodes giving 1mm depth at three different currents (i.e. 10 A, 15 A & 20 A). The surface roughness parameters average roughness (Ra), average maximum height of the profile (Rz), maximum roughness depth (Rzmax) and the mean spacing of the asperities (Rsm) of machined surfaces of each material at corresponding currents (10A, 15A & 20A) were measured by Handy surf E-354 Surface testing analyzer, model EMC-S24B. The sampling length of machined surface for each measurement was taken as 1.25mm.

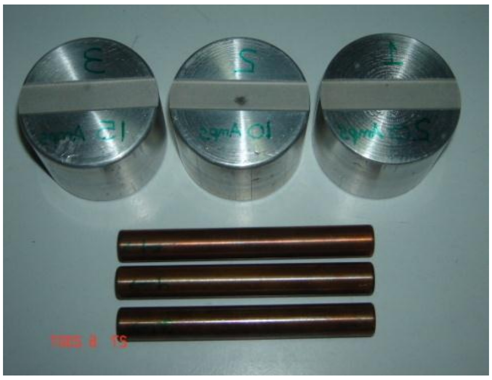

Fig 3(a). Shows Cu Tool's & Al Work piece's

Fig 3(b). Shows Cu Tool's & Die steel Work pieces

The hardness analyzed is the Vickers one which is characterized by a rhombus print on the work piece surface due to the applied charge by the pyramid diamond shape .The micro hardness of machined surfaces of Al & Die steel samples at corresponding currents (10A, 15A & 20A) before and after machining ware obtained by micro hardness tester FM-300e, Future Tech. Corp., made in Tokyo, Japan. The machining time were also recorded for carrying out analysis. The current is the process parameter which is considered in this study.

3. Results and Discussion

3.1 Variation of surface roughness parameters

The variation of average roughness (Ra), average maximum height (Rz) , maximum roughness depth (Rzmax) and the mean spacing of the asperities (Rsm) parameters on surface of Al and Die steel work samples machined at 10, 15 & 20 Amps current for 1 mm depth erosion ware considered. The values of surface roughness parameters (Ra, Rz, Rzmax & Rsm) on Al and Die steel work samples for corresponding currents 10, 15 & 20 Amps are shown in Tables 3& 4.

Table 3: The surface roughness parameter values for Al work pieces

Aluminium work pieces				
Current (amps)	Ra (µm)	Rz (µm)	Rzmax (µm)	Rsm (µm)
10	1.62	9.03	10.96	59.03
15	1.83	10.25	11.74	61.90
20	1.97	10.86	14.54	83.80

Table 4: The surface roughness parameter values for Die steel work pieces

Die steel work pieces				
Current (amps)	Ra (µm)	Rz (µm)	Rzmax (µm)	Rsm (µm)
10	1.99	10.02	10.90	73.60
15	2.19	11.50	11.40	77.30
20	2.55	13.43	15.40	107.50

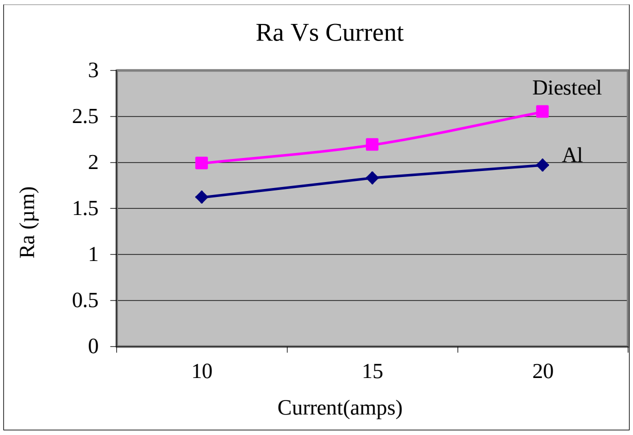

Fig .4 Average roughness (Ra) vs Current for Al & Die steel sample

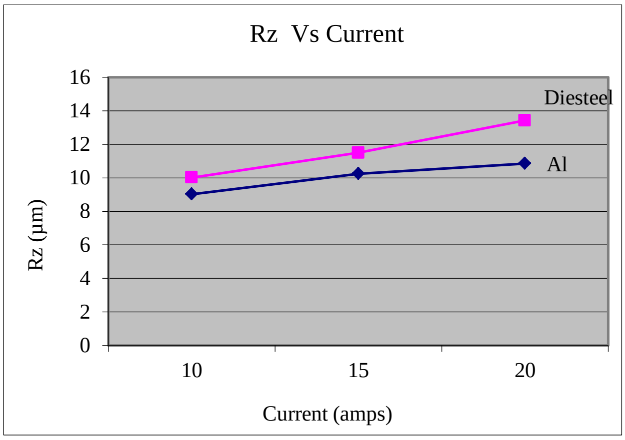

Fig .5 Average maximum height (Rz) vs Current for Al & Die steel samples

When current is increased from 10A to 20A for Al & Die steel work samples the average roughness (Ra) values gradually increases from 1.62 to 1.97 µm and 1.99 to 2.55 (fig.4), average maximum height (Rz) slowly increases from 9.03 to 10.86 µm and 10.02 to 13.43 µm (fig.5), maximum roughness depth (Rzmax) also gradually increases from 10.96 to 14.54 µm and 10.90 to 15.40 µm (fig.6), but the mean spacing of the asperities (Rsm) has sharply increased from 59.03 to 83.80 µm and 73.60 to 107.50 µm (fig. 7), respectively.

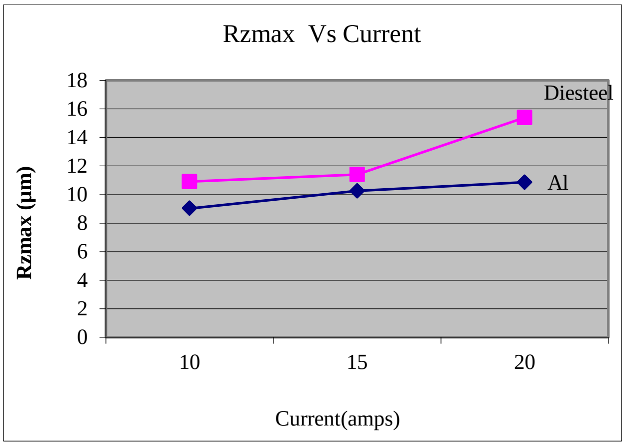

Fig .6 maximum roughness depth (Rzmax) vs Current for Al & Die steel samples

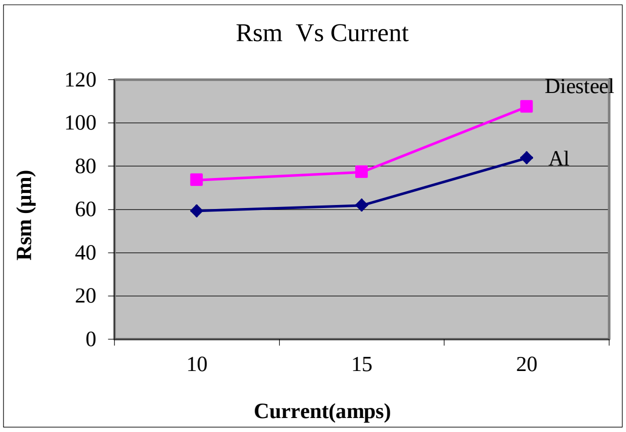

Fig .7 The mean spacing of the asperities (Rsm) vs Current for Al & Die steel samples

At a low current, a small quantity of heat is generated and a substantial portion of it is absorbed by the surroundings. As a result, the amount of utilized energy in melting and vaporizing the electrodes is not so intense. However, with an increase in pulse current and with a constant amount of pulse on-time, a stronger spark with higher thermal energy is produced, and a substantial quantity of heat will be transferred into the electrodes.

Furthermore, as the pulse current increases, discharge strikes the surface of the sample more intensely, and creates an impact force on the molten material in the crater and causes more molten material to be ejected out of the crater, so the surface roughness of the machined surface increases.

3.2 Study of micro hardness

The micro hardness analysis was performed & the Vickers hardness values as shown in the Table 5 were obtained. The hardness values for Al & Die steel work samples before machining ware 75.03 HV and 390.40 HV respectively.

Table 5: Micro hardness of Al & Die steel work pieces

S.No	Current (Amps)	Vickers Hardness (Al)	Vickers Hardness (Die steel)
1	10	112.66	394.35
2	15	154.36	414.55
3	20	48.66	352.70

The hardness values at corresponding currents 10, 15 & 20 Amps for Al pieces ware 112.66, 154.36 & 48.66 HV and that of Die steel pieces ware 394.35, 414.55 & 352.70 HV.

As shown in the fig. (8), the hardness values of Al & Die steel work samples ware optimum at 15 Amps current and also hardness of both samples increased after machining when compared to before machining.

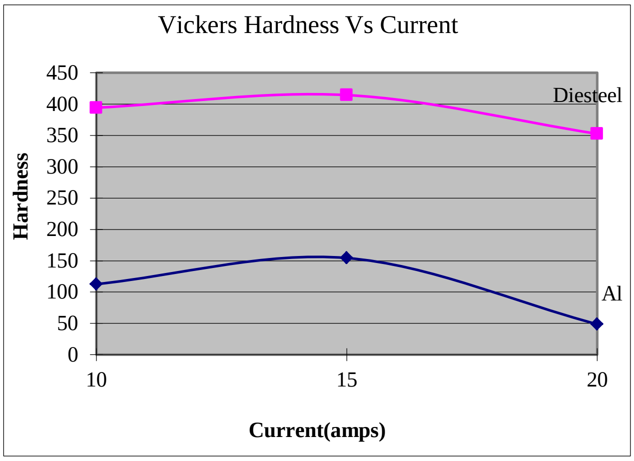

Fig .8 Vickers hardness vs Current for Al & Die steel samples

The EDM process systematically induces an increase in the hardness of the outer layer of machined surfaces up to certain optimal values of process parameters however the increase in rate also depends upon the type of machined material.

3.3 Variation in the machining time

The machining time for both samples at corresponding currents is depicted in Table.6.When the current is increased from 10A to 20A, the corresponding machining time was decreased from 212 to 160 min for Al as shown in Fig .9(a) and 302 to 229 min for Die steel samples as shown in Fig .9(b).

Table 6: Machining Time for Al & Die steel work pieces

Current (Amps)	Machining Time in min	
	Al	**Die steel**
10	212	302
15	162	231
20	160	229

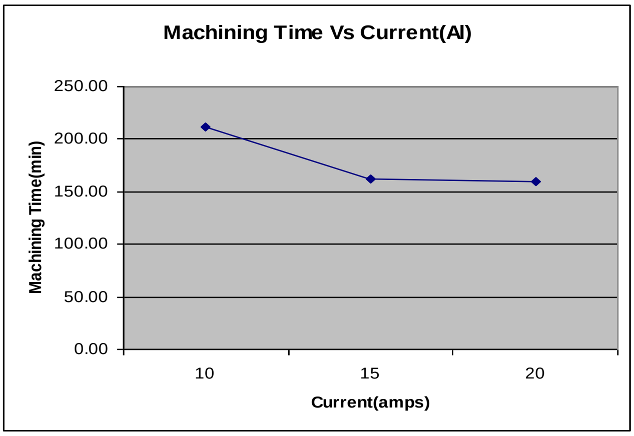

Fig .9(a) Machining Time vs Current for Al

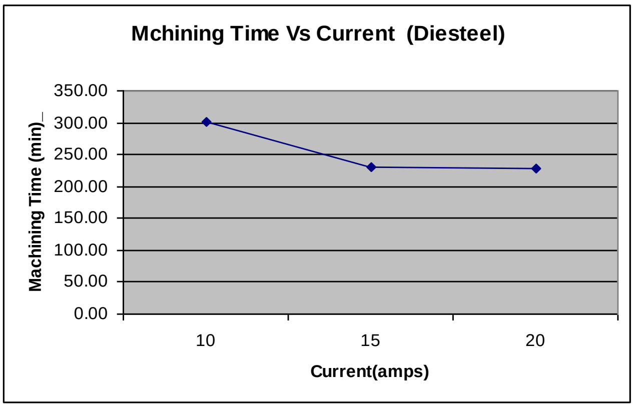

Fig .9(a) Machining Time vs Current for Die steel samples

When peak current increases a stronger spark with higher thermal energy is produced allowing more spark energy to flow from tool into work piece which causes craters and pits on the sample and machining becomes faster.

4. Conclusions

Results from the experimental investigation to study the various surface roughness parameters and micro hardness for surface integrity in sink EDM process have been presented. The leading conclusions drawn are as follows:

1. It was observed that the surface roughness parameters (Ra, Rz, Rzmax and Rsm) of both Al & Die steel samples ware influenced by current. The increase in pulse current leads to increase in the values of surface roughness parameters indicating that low current produce good surface finish quality.
2. It was evident that there was a gradual increase in Ra, Rz & Rzmax parameters and sharp increase in Rsm parameter as the current was increased.
3. Results of the study show that increase in current leads to high energy discharge which increases instability and therefore, the quality of the work piece surface become rougher.
4. It was evident that the hardness of both Al & Die steel samples was increased after machining at corresponding currents & was optimum at 15 Amps.
5. Lower discharge current should be used for a lower hardened surface but consequently the machining time will increase.
6. It was observed that the machining time decreases as the current increases and due to hardness the machining time of Die steel work samples were more compared to Al samples.

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