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An Automation System Of Electrical Discharge Machining (Edm) Using Psoc

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Abstract:
Nowadays, shortening cycle time and cost reduction is obligatory in competitive automotive market. Electrical discharge machining (EDM) is one of the earliest non-conventional machining has experienced steady growth in engineering applications in order to fabricate complex geometry parts. This paper has presented a new automated system using Programmable System-on-Chip (PSoC) for Die-sinking EDM in order to enhance Material Removal Rate (MRR).

Keywords: *electrical discharge machining, automated system, material removal rate.*

INTRODUCTION

Electrical Discharge Machining (EDM) is a non-contact process based on thermoelectric energy between a workpiece and an electrode that has widely used in many applications especially in automotive industry [1-4]. Moreover, many hard-to-cut and brittle materials can be economically processed by EDM based on the thermal erosion principal [5]. In the development of EDM, there have many types of this technique such as sinking EDM [6, 7] wire-cut EDM [8, 9] grinding EDM [10] EDM milling [11] and micro-hole EDM drilling [12] have been developed since it was innovated in the late 1940s by the former Soviet Union scientists, Dr Boris Lazarenko and Dr Natalya Lazarenko in Moscow [13, 14]. Until now, the EDM system still in improvement and has extensively used to machine various conductive materials such as carbide, ceramics and others.

In EDM process, the electrode is moved towards the workpiece until the gap is small enough, then the electric field become strongest and the voltage become sufficiently high [15]. Then, the dielectric fluid in the sparking gap breaks down into ionized particles and an ionization channel is started. After that, in the same time, when the voltage at the sparking gap exceeds the voltage gap, the circuit is opened and drastically reduces the temperature at the sparking gap, a collapse of the vapor bubble is triggered and high-energy spark temperature with the pressure also generated [16]. Lastly, the sudden thermal energy is produced that causes melting and vaporization of the workpiece which creates small crater. The eroded particles in form of debris are removed from the electrode and workpiece surface with flushing process [17]. Generally, EDM system consists of several basic elements which are power supply, spark generator or pulse generator, servo system, mechanical structure and dielectric fluid [18] as shown in Fig 1.

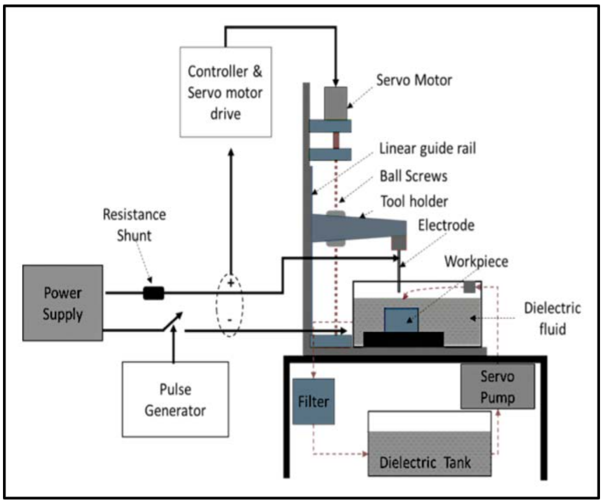

Fig 1. Schematic diagram of EDM system.

Numerous study of Die-sinking EDM design technique in improving and performance measures.

According to researcher, Yahya [19] has explained the optimization of copper and graphite electrode to measure MRR performances in die-sinking EDM system onto steel workpiece using eZdsp controller. Besides that, Zhang [20] have described the processing efficiency and quality have been improved in micro-EDM using interval type-2 fuzzy logic based two stage servo feed controller. After that, Andromeda [21, 22] has studied the optimization of Proportional Integral Derivative (PID) to define gain parameter in servo actuator system using Particle Swarm Optimization and Differential Evolution algorithm. Then, Pawade and Banwait [23] have discussed the only 3% of researchers focus on automation of EDM process and then suggested a new Programmable logic controller (PLC) based flexible controller for die sinking EDM in order to achieve high level automation and to reduce the operator dependency. Whereas, Jesudas and Arunachalam [24] have developed spark gap controller for a tabletop micro EDM setup using AT89C51 microcontroller. Afterwards, Yadav [25] have investigated the controlled melting and vaporization of excess material from difficult to machine, electrically conductive material with stringent design requirements using thermal energy generated by spark between two electrodes completely dipped in dielectric and applying a pulsating voltage between them. Moreover, Thampi [26] proposed a cost effective automatic spark gap adjustment system for a tabletop micro EDM experimental setup using Arduino microcontroller. Regarding to another researcher, Tseng [27] have been developed an automated EDM system with real-time monitoring to obtain real-time status retrieval and display of crucial parameters on a screen using VisSim software, Arduino microcontroller and PID controller.

EXPERIMENTAL WORK

Experiments were carried out using 2 mild steel samples that have density, ρ= 7.85 mg/mm3. Fifteen experimental runs were performed individually using EDM-Ben Fleming system and EDM-PSoC system at 2 Ampere of current setting, respectively. In addition, there have some parameters were considered as tabulated in Table 1.

Table 1. Parameter setup for Lab scale of EDM system.

Parameter used	**Value set**
T_{on}	60 µs
T_{off}	30 µs
V_{oc}	100 V
V_{gap}	15 V – 20 V

There have two assumptions of pressure dielectric fluid and current consumption were considered as constant in this experiment. Prior to running experiment, the weight of both samples were taken before and after machining using electronic balance (Shimadzu ATX224). Then, the sample with dimensions (30x10x10) mm^3 was placed on adjustable mini jaw bench clamp. Pure tungsten was used as electrode material in cylindrical form with diameter 1mm. Dielectric medium used in this experiment is Vitalube EDM 99 SD. After machining process, the sample was dried using air dryer to remove dielectric medium on the sample to get accurate results. The MRR values were calculated using Equation 1 [28] and tabulated in Table 2.

$$MRR = (W_i - W_f)/(T)(\rho) \qquad (1)$$

Where W_i and W_f represents the weight of workpiece before and after machining process. Then, ρ indicates the density of workpiece whereas T is time of machining (measured in minutes).

EDM-Ben Fleming System

In EDM-Ben Fleming system, the pulse generator has been control using 555 timers integrated circuit(IC) where T_{on} and T_{off} was set using potentiometer. When the duration was turned ON, Hexfets were be ON position to allow the current flows in order to make discharge process. In the meantime, when the interval was turn OFF, Hexfets were be OFF position during process. During the machining process, voltage feedback was send the signal to comparator circuit. When the voltage feedback value was higher than the reference value, then it was generated a drive signal to drive servo mechanism in order to decrease the gap between the electrode tool and workpiece, and vice versa.

Proposed Automation System (EDM-PSoC System)

The Programmable System-on-Chip (PSoC) microcontroller have been selected to implement in die-sinking of EDM design system. A single PSoC device have some advantages such as it able to integrate almost 100 digital and analog peripheral functions, minimize board space, reducing design time, low power consumption and system cost while improving system efficiency [29-31].

In PSoC microcontroller, there consists of a CPU core, configurable analog and digital blocks which is a combination of several chips performing function together. This EDM-PSoC system divided in two elements which is mechanical part and electrical part. In mechanical part contains of EDM structure, pump, filter, tank, tool and workpiece whereas in electrical part contains of DC power supply unit (SMPS type), PSoC, servo motor, Input-output board (IO) and input button. The power supply unit and EDM structure of the existing die sinking EDM was worked as an input to PSoC in this system.

The process of EDM-PSoC system is started from inserted input data in parameter setting (time, pulse for T_{on} and T_{off} and voltage gap) were set up through button and viewed on a LCD display. Then, PSoC will be send the data signal through IO card to control the tool position, pulse time (T_{on} and T_{off}), power supply output and flushing speed as per earlier setting. The voltage and current gap from die sinking system act as data feedback in PSoC microcontroller to control the gap between tool and workpiece using proportional integral derivative controller (PID) algorithm. This EDM-PSoC process is repeated until the time is finished. Fig 2 indicates the schematic diagram of EDM-PSoC system.

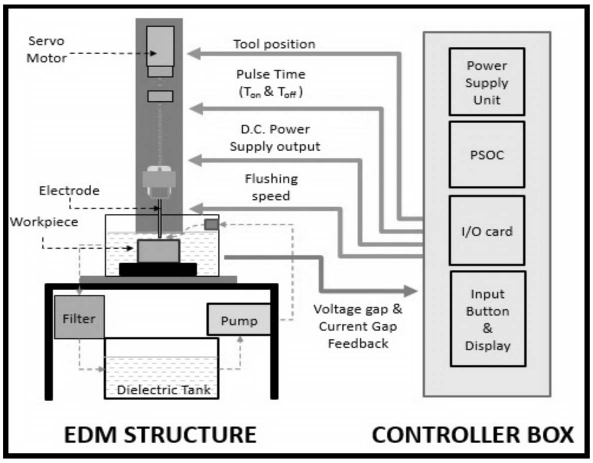

Fig 2 Schematic diagram of EDM-PSoC system.

RESULTS AND DISCUSSIONS

Both EDM-Ben Fleming system and EDM-PSoC system have been performed with thirty runs on two samples. Table 2 shows the comparison of MRR values for fifteen runs between both systems, respectively. The highest value of MRR using EDM-Ben Fleming is 0.0115 mm^3/min, whereas EDM-PSoC system is 0.0153 mm^3/min. Besides that, the lowest MRR value for EDM-Ben Fleming system is 0.0076 mm^3/min and EDM-PSoC system was 0.0127mm^3/min, respectively.

Table 2. Experimental results of MRR values for EDM-Ben Fleming system and EDM-PSoC system.

Runs	EDM-Ben Fleming			EDM-PSoC		
	Weight Before (mg)	***Weight After (mg)***	***MRR (2A) (mm3/min)***	***Weight Before (mg)***	***Weight After (mg)***	***MRR (2A) (mm3/min)***
1	22.1107	22.1100	0.0089	23.3913	23.3903	0.0127
2	22.1100	22.1088	0.0078	23.3903	23.3881	0.0140
3	22.1088	22.1065	0.0098	23.3881	23.3845	0.0151
4	22.1065	22.1032	0.0105	23.3845	23.3804	0.0131

5	22.1032	22.1002	0.0076	23.3804	23.3753	0.0130
6	22.1002	22.0995	0.0089	23.3753	23.3743	0.0132
7	22.0995	22.0983	0.0078	23.3743	23.3719	0.0153
8	22.0983	22.0960	0.0098	23.3719	23.3685	0.0144
9	22.0960	22.0927	0.0105	23.3685	23.3638	0.0150
10	22.0927	22.0897	0.0076	23.3638	23.3583	0.0140
11	22.0897	22.0889	0.0095	23.3583	23.3573	0.0132
12	22.0889	22.0872	0.0108	23.3573	23.3549	0.0153
13	22.0872	22.0850	0.0093	23.3549	23.3513	0.0150
14	22.0850	22.0814	0.0115	23.3513	23.3467	0.0147
15	22.0814	22.0775	0.0099	23.3467	23.3410	0.0145
	Means $\bar{x}$		0.0094	Means $\bar{x}$		0.0142
	Standard Deviation(s)		0.0012	Standard Deviation(s)		0.0009

A comparison graph of MRR values for fifteen runs between EDM-Ben Fleming system and EDM-PSoC system as shown in Fig 3. Based on the graph, the MRR value is higher using EDM-PSoC system (red color) as compared with EDM-Ben Fleming system (black color). This is can be explained on the basis of increase in the rate of discharge energy, as high concentration of discharge energy in the spark gap leads to rapid melting and metal vaporization, which is leads to rises of MRR [32]. Fig 3 represents the MRR values for both system are increase horizontally shows the stability of MRR both experimental.

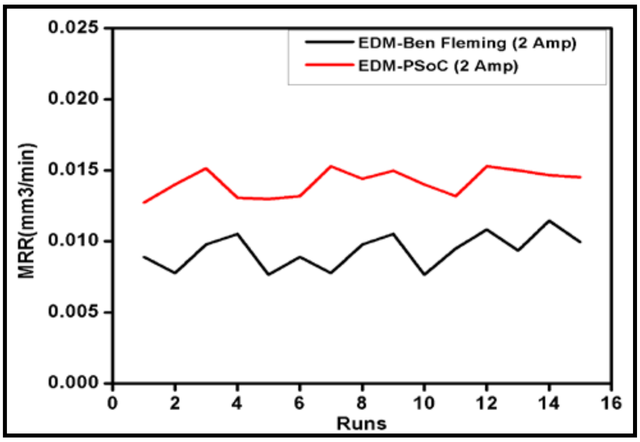

Fig 3 Comparison of MRR for EDM-Ben Fleming system and EDM-PSoC system.

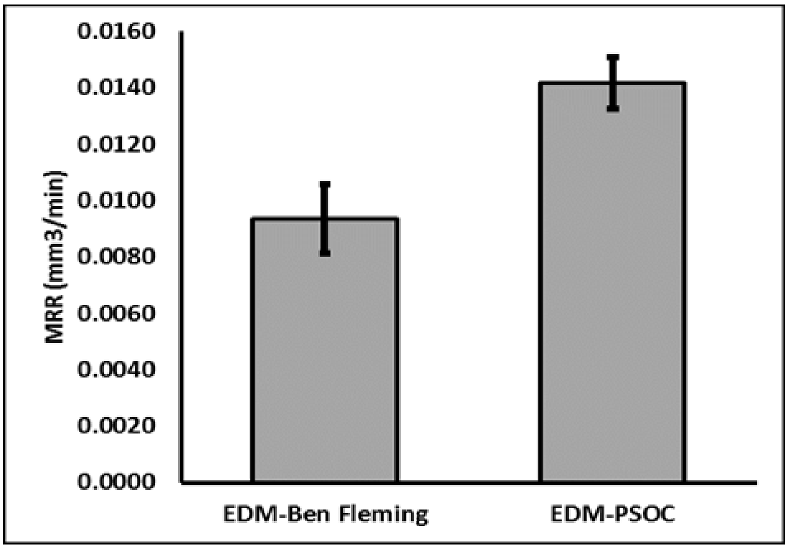

Fig 4 Mean for both system with their respectively standard deviation.

Based on Table 2 and Fig 4, the mean MRR value of runs using EDM-Ben Fleming system is 0.0094 mm^3/min. Whereas, the mean MRR value of samples for EDM-PSoC system is 0.0142 mm^3/min. The standard deviation value for EDM-PSoC system (0.0009) shows lowest as compared with EDM-Ben Fleming system (0.0012). The EDM-PSoC system shows higher consistency of MRR compared with EDM-Ben Fleming system due to its standard deviation value nearest with means data.

CONCLUSIONS

In this research, performance of EDM has been analyzed for MRR using EDM-Ben Fleming system and EDM-PSoC system. Then, the effect of high speed processing data analyzes using PID algorithm in PSoC microcontroller shows higher MRR as compared by EDM-Ben Fleming system and leads to improving system efficiency by 51%. The higher consistency of MRR when using EDM-PSoC system proves that the machining condition more stable as it able to remove the material nearly consistent for each run on the sample.

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