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Proposed Automatic Spark Gap Adjustment System for a Tabletop Micro Edm

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ABSTRACT:EDM is an electro-thermal non-traditional machining process.This technology is increasingly used due to the requirement of high precision, complex shapes and high surface finish. After conducting a literature review on the various notable works in the field of Electro discharge machining,it was noted that the importance of micro EDM is increasing day by day. This work is mainly focused to review and propose a cost effective automatic spark gap adjustment system for a tabletop micro EDM experimental setup.
Keywords: Non-traditional machining, Micro EDM,Spark gap controller, automation.

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I. INTRODUCTION

The demand for miniature components are increasing every day. Micro EDM is a very promising machining operation to meet the requirements in the production field due to the high precision, surface finish and simplicity. This metal cutting process is mainly used for hard metals or those materials which are very difficult to cut with traditional techniques. The working principle of EDM is that it converts electrical energy into thermal energy of spark. In this machining process the material from the work piece is removed by the controlled wearing action caused due to the repeatedly occurring spark ejections between the tool and work piece immersed in a dielectric fluid. Here the machining takes place mainly due to spot vaporization of the metallic particle and melting.

The new developments in the field of materials like alloys, composites, etc. has increased the importance of EDM. So it is necessary to make further developments in this machining process. From the literature review it is noted that only few works have focused on the spark gap controller. The spark gap between the tool and work piece is maintained in a very small range of 10-125µm.So this works focus mainly on the review and proposal of a cost effective automaticspark gap adjustment systems for a tabletop Micro EDM. [14,15]

II. LITERATURE REVIEW

Jesudas T et al. focused to develop a spark gap controller for a table top micro EDM setup. They conducted 27 experiments on 316L stainless steel to assess the performance of the controller. The number of experiments to be conducted was generated using full factorial design methodology. The parameters like voltage, spark gap, capacitance were considered and the output obtained was MRR. The results shows that voltage is a major contributor for MRR whereas spark gap is a minor contributor than capacitance. [2]

Muralidhara et al. developed a directly coupled piezoactuated tool feed mechanism prototype. The piezoactuator was used to feed the tool and also to sense the displacement of tool with respect to a reference position. The simulation results for the piezoactuator displacement were compared with the experimental work and it was observed that there was 15% error. In order to control the tool feed rate, a separate control system was developed in which the gap voltage was considered as an important parameter. Micro-machining experiments were conducted with copper as work piece whereas copper and tungsten as tool. [12]

Yong et al. proposed and developed a prototype micro EDM with an inchworm type of micro feed mechanism. It features high feed accuracy and quick response to maintain micro gap between the electrodes and work piece during machining. In this developed setup, a micro hole of diameter less than 50 µm was been obtained. [17]

Said et al. developed and demonstrated an adaptive tip withdrawal technique. The technique was operated by monitoring the deposition current gradient, and the system also triggered tip positioning at a speed proportional to the detected current gradient. [16]

Takashi et al. introduced vibration assisted machining to micro EDM using PZT to flush out the debris between the electrodes. Using vibration assisted machining a small square shaft was also fabricated. They concluded that the vibration assisted machining improves the machining stability and reduces machining time. [13]

Ashok Kumar et al. has done a work to machine EN-19 tool steel using a U shaped tubular copper electrode and internal flushing was implemented. The experimental design was done using Taguchi design approach with the help of minitab software. They have conducted 18 experiments and the results were in terms of MRR, TWR and OC. The main necessity while machining will be that MRR should be maximum and TWR should be minimum, so from the result obtained MRR increases with current but when the pulse on time increases the MRR will decrease and TWR also increases. When pulse on time was minimum 50µs, MRR was 4.634 mm3/min and TWR was 0.0016gm/min.[10]

P.S. Rao et al. has fabricated a table top EDM and the performance of the system was checked using copper and graphite as tool on mild steel, HSS work piece. The parameters that they varied were current, voltage, tool-work piece polarity. From the results of the work it was concluded that copper will provide better surface finish whereas graphite tool will provide higher depth of cut and MRR. The system fabricated can be improved by using a PLC. [8]

M.Mustafaiz Ahmad et al. investigated the effect of surface roughness of titanium grade 2 using a circular shaped copper tool in an already existing EDM system. The experiments were conducted by varying the process parameters like current, pulse on time, duty cycle and breakdown voltage under different levels. An L 18 OA was created based on taguchi's design .Minitab software 17 was used by them to analyze the results obtained and they partially validated the results experimentally. They concluded that the optimal condition for surface roughness on titanium grade 2 with copper electrode was 16A peak current, 100µs pulse on time, 12% duty cycle and 70V voltage.[1]

Arul Dassjames.D et al. studied about the emerging near dry wire cut EDM and then the experimental performance has been initially presented based on taguchi's design of experiments. The dielectric used is a mist of air and oxygen. They claim that it is a stable ecofriendly machining method to produce high degree of surface finish with considerable MRR. The significant parameters that were identified by taguchi for the near dry EDM were gap voltage, pulse width, pressure of air/oxygen mist and discharge current. The material chosen for the work was HSS-M2. The conclusion from the works was that good machining speed and surface finish was achieved in moderate air/oxygen mist pressure, so as the velocity of dielectric medium increases the spark transfer between the tool and work piece will be restricted at maximum pressure and from the comparative study done, the MRR of oxygen mist near dry WEDM process is 20% higher than air mist dielectric medium but the surface finish of oxygen mist medium has 17.3% lower than the air mist dielectric medium in the near dry EDM. [3]

Jon Elson et al. in his machining page he has mentioned about an electrical circuit for EDM spark generation. The circuit is an RC type. [5]

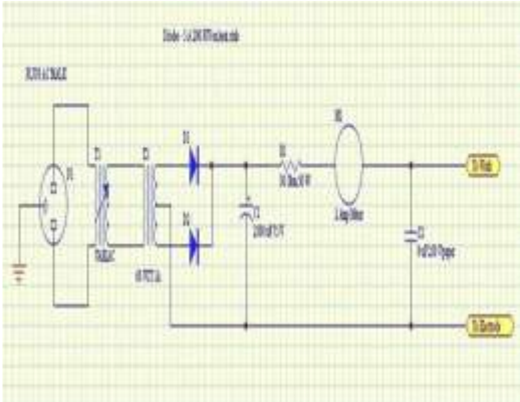

Fig 1. Electrical circuit for a mini EDM system [5]

M.P.Jahan etal. studied the effect of operating parameters on machining characteristics. A micro EDM machining of AL2024 alloy was conducted under different operating parameters like capacitance, resistance, input voltage, spindle speed, gap control factor, gap feed rate and gap threshold voltage as a result, the results obtained were MRR, TWR, depth of cut and SR. It was found that when capacitance increases, the energy per pulse will be high and the crater formed will be large, thus MRR increases at higher values of capacitance which makes the surface finish poor. It is also observed that TWR decreases with increase in capacitance. [6]

Fuqiang Hu et al. in his work conducted a study on the effect of process parameters and tool material on machining characteristics. When voltage is increased the TWR increases gradually, this is mainly due to increase in the discharge energy with enlargement voltage and the explosive power of spark increases at the same time. When OCV is lower than a certain value, tool wear increases. The reason is that the spark gap will be small with decrease in OCV, which results in the difficulty to remove chip formed and will make it easy to form a secondary discharge. [11]

J. T. Gudmundsson et al. has done a study on the high power impulse magnetron sputtering discharge. From this work an Electric circuit diagram illustrating a pulse generator with a preionizer was obtained. A dc power supply maintains a conventional dc magnetron discharge. The storage capacitor is charged through a thyristor switch from a charging circuit and a trigger circuit discharges the capacitor through another a thyristorswitch. This circuit is similar to the EDM spark generating circuit using IGBT.

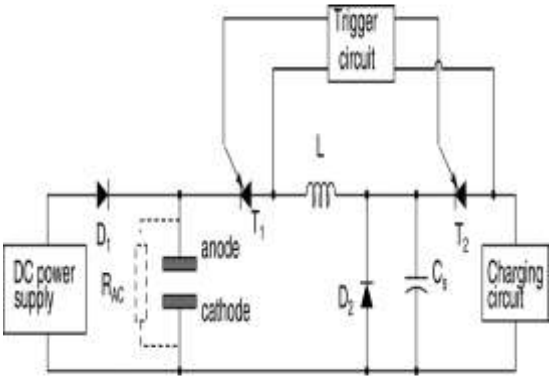

Fig. 2 Electrical circuit for pulse (spark) generation [9]

III. PROPOSED AUTOMATIC SPARK GAP ADJUSTMENT SYSTEM

The spark gap between the tool and work piece have a very important role in the EDM process. The proper removal of material from the small spark gap is required to generate an accurate shape and size which can be only attained easily by controlling the spark gap. In the proposed system to automatically adjust the spark gap, a combination of mechanical, electrical and electronic systems are required.

The proposed mechanical part for the system is a screw and nut arrangement with a guide way as shown in fig. 3. When the screw is rotated by a stepper motor, the nut will be moving up and down so that a vertical displacement (movement along the Z axis) is obtained. The tool is attached to the nut with the help of an electrically insulated material. Therefore the tool moves along with the nut in the provided guide way. The container provided at the bottom of the mechanical frame of the system maintains the work piece in a submerged condition and the dielectric fluid can be circulated using a pump. The commonly available screw and nut is having a pitch of 1mm which can be used for this proposed mechanical system. The mechanical frame can be made of acrylic sheet so that the system can be made light weight and a tool holder need to be connected to the nut which can be made of PLA or any other electrically insulated material using a 3D printer.

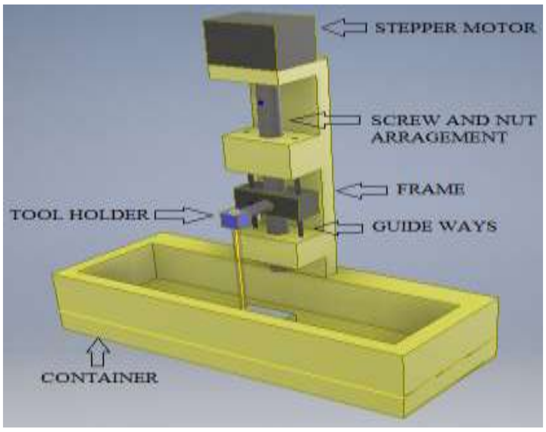

Fig. 3 Proposed Mechanical system

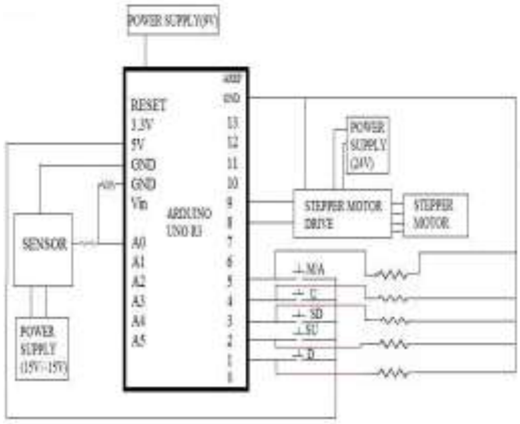

Fig. 4 Proposed Electrical system controlled by Arduino Uno R3

The proposed electrical system controlled by a microcontroller is shown in fig. 4. In this circuit the microcontroller used is an **ARDUINO UNO R3** board. Arduinomicrocontroller has been selected because of its low cost and it is easily available. The inputs to the microcontroller and its purposes are the following:

- M/A – when this toggle switch is ON the tool can be moved manually.
- U – when the M/A switch is ON then if this push button switch is pressed ON then the tool will move up a large distance.(200 input pulse will be provided to the stepper motor as per the program).
- SD – when the M/A switch is ON then if this push button switch is pressed ON then the tool will move down only a small distance. (1 input pulse will be provided to the stepper motor as per the program).
- SU – when the M/A switch is ON then if this push button switch is pressed ON then the tool will move up only a small distance. (1 input pulse will be provided to the stepper motor as per the program).

- D – when the M/A switch is ON then if this push button switch is pressed ON then the tool will move down a large distance. (200 input pulse will be provided to the stepper motor).
- SENSOR – when the M/A switch is ON then the highest value of voltage detected during spark erosion will be noted and saved in the program as gap voltage. When the M/A switch is OFF then the voltage value from the sensor and gap voltage saved will be compared and the tool will be moved up and down as per the instructions given in the Arduinoprogram. So the spark gap can be maintained automatically. The sensor that can be used is an LEM sensor which will give an analogue output signal and a voltage signal. It should have a response time of 7µs.(when an analogue signal is provided to the microcontroller if it is not working properly then use an Analogue Digital Converter to get a digital signal which can be provided to the microcontroller)

The output from the microcontroller will be provided to the stepper motor drive. The micro step configuration should be available up to 1/128. So that one step can be converted in to 128 micro steps. From the stepper motor drive the signal will be provided to the stepper motor. The stepper motor should have a low step angle of $1.8^0$and the load acting on the motor will be very low because of the light weight of tool and tool holder and there is no cutting force.

So when we select a screw of 1mm pitch, it means that for 360^0 rotation, 1mm vertical displacement will take place. Therefore for 1.8^0 rotation, 0.005mm vertical displacement will be happening. When a micro stepping configuration of 1/128 is set, then the vertical displacement will be 0.04 micron with such a small vertical displacement we can easily adjust the spark gap of a Micro EDM.

The logic for automating the spark gap control is shown in fig. 5. The logic was generated in ARDUINO software. The working of the logical program is that initially the system will be in manual mode by switching ON the M/A toggle switch. During this time we can manually move the tool up and down using SU, SD, U, D Push button switches and the voltage between the tool and work piece is measured continuously and the highest value from the sensor will be saved as gap voltage. When a spark occurs the capacitor will be discharging so during that period the voltage will be high. So that voltage will be saved as gap voltage. After that the manual mode is turned OFF, then the system will be working automatically. So the gap voltage and sensor value is continuously compared.

- When the gap voltage is less than the sensor value, the tool needs to be moved forward.
- When the gap voltage is more than the sensor value, the tool needs to be moved backward.
- When the gap voltage is equal to the sensor value, the tool will stay in that position.

```
int manual = 5;
int up =4;
int down=1;
int stepup=2;
int stepdown=3;
int sensor = A0;
int gapvoltage = 0;
int sensorvalue = 0;
int dirpin = 8;
int steppin = 9;
void setup()
{
  // put your setup code here, to run once:

pinMode(manual, INPUT);
pinMode(up, INPUT);
pinMode(down, INPUT);
pinMode(stepup, INPUT);
pinMode(stepdown, INPUT);
pinMode(dirpin, OUTPUT);
pinMode(steppin, OUTPUT);


}
void clockwise(int t)
{
  digitalWrite(dirpin, LOW);
  for(int i=0;i<t;i++)
  {
    digitalWrite(steppin, LOW);
    delay(1);
    digitalWrite(steppin, HIGH);
    delay(1);
  }
}
void anticlockwise(int t)
{
  digitalWrite(dirpin, HIGH);
  for(int i=0;i<t;i++)
  {
    digitalWrite(steppin, LOW);
    delay(1);
    digitalWrite(steppin, HIGH);
    delay(1);
  }
}
```

```
void loop()
{
 sensorvalue = analogRead(sensor);
 if (manual == HIGH)
 {
   if (stepdown == HIGH)
   {
    anticlockwise(1);
   }
   if (stepup ==HIGH)
   {
    clockwise(1);
   }
   if (down == HIGH)
   {
    anticlockwise(200);
   }
   if (up ==HIGH)
   {
    clockwise(200);
   }
   if(sensorvalue>gapvoltage)
   {
     gapvoltage=sensorvalue;
   }
 }
 else
 {
   if(gapvoltage>sensorvalue)
   {
     clockwise(1);
   }
   if(gapvoltage<sensorvalue)
   {
     anticlockwise(1);
   }
 }
}
```

Fig. 5 Arduino logic for controlling spark gap

1.1. COST ESTIMATION OF THE PROPOSED SYSTEM

- The Mechanical structure consisting of frame-container, tool holder, lead screw-nut and guide way = Rs.3000
- Sensor = Rs.3000
- Arduino UNO R3 board = Rs.500
- Stepper motor = Rs.1000
- Stepper motor drive = 7000
- Power supply = Rs.1500
- Miscellaneous = Rs.4000

TOTAL = Rs.20000

IV. CONCLUSION

In this paper, a review was conducted based on the few notable works done in the field of EDM and the paper focused mainly on the spark gap controller for a tabletop Micro EDM. The proposed automatic spark gap adjustment system can be fabricated cost effectively compared to the commercially available system.

REFERENCES

[1]. M.Mustafaiz Ahmad, A Parametric Experimental Design Study of EDM Process Parameters in Machining of Titanium Grade 2,International Journal of Aerospace and Mechanical Engineering Volume 3, August 2016.

[2]. Jesudas T, Arunachalam RM, Development and Performance study of Spark gap Controller for Table Top Micro-EDM,Asian Journal of Research in Social Sciences and Humanities Vol. 6, No. 3, March 2016,pp.145-155.(ISSN 2249-7315).

[3]. Arul Dassjames.D, Experimental Study of Eco-friendly Wire-Cut Electrical Discharge Machining Processes, International Journal of Innovative Research in Science, Engineering and TechnologyVol. 5, Issue 1, Januray 2016.

[4]. Trupti G. Raut,A Review on Optimization of Machining Parameters in EDM, International Journal of Innovative Research in Science, Engineering and Technology,Vol. 4, Issue 3, March 2015.

[5]. Jon Elson's Machining Page

[6]. M.P.JahanPegahKakavand, E.L.M. Kwang, M.Rahman, Y.S.Wong, 2014, An Experimental invesigation into the micro electric Discharge machining behviour of Aluminium alloy (AA 2024) , Int. J AdvManuf Technology.

[7]. Sreenivasa Rao M,Review on Wire-Cut EDM Process, International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6,Pg: 12-17 (2013).

[8]. P.S. Rao, Performance of a Low Cost Tabletop Die Sinker Electric Discharge Machining [EDM] Unit, International Journal of Modern Engineering Research, Vol.2, Issue.3, May June 2012 pp-1320-1325.

[9]. J. T. Gudmundsson, N. Brenning, Daniel Lundin and Ulf Helmersson, High power impulse magnetron sputtering discharge (2012), Journal of Vacuum Science & Technology. A Vacuum Surfaces and Films, (30), 030801.

[10]. Ashok Kumar, Experimental Investigation of Machine parameters For EDM Using U shaped electrode of EN-19 tool steel,

International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Vol. 1, Issue 4, 2011, pp.1674-1684 1674.

[11]. Fuqiang Hu B.Y.Song, J.C.Bail, P.J.Hou, H.C.Chen and H.Zhang, 2010, Micro EDM for an Aluminium Matrix Composite, Key Engineering Materials, Vols. 447-448.

[12]. Muralidhara, Nilesh J Vasa, SingaperumalMakaram, Investigations on a directly coupled piezoactuated tool feed system for Micro electro-discharge machine, International Journal of Machine Tools & Manufacture (2009).

[13]. Takashi Endo, Takayuki Tsujimoto, Kimiyuki Mitsui, (2008), "Study of vibration assisted micro-EDM- The effect of vibration on machining time and stability of discharge", Precision Engineering, Vol.32, pp. 269–277.

[14]. Jose Mathew, Hashim V, Sooraj V.S, M.Rahman, Experimental analysis of micro hole making in die steel using Micro Electric Discharge Machining, Fifth International Conference on Precision,Meso,Micro and Nano Engineering, College of Engineering, Trivandrum, India, Dec 2007,pp.279-285.

[15]. Jose Mathew, V.B.Suresh Kumar, Somashekhar K.P, Investigation into the influence of process parameters on Micro Wire EDM, Fifth International Conference on Precision,Meso,Micro and Nano Engineering, College of Engineering, Trivandrum, India, Dec 2007,pp.287-293.

[16]. Said, R. A. "Adaptive Tip-Withdrawal Control for Reliable Micro fabrication by Localized Electro deposition", Journal of Micro electromechanical Systems Vol.13, No. 5, pp. 822-832, 2004.

[17]. Yong Li, Min Guo, Zhaoying Zhou and Min Hu, "Micro electro discharge machine with an inchworm type of micro feed mechanism", Journal of the International Societies for precision engineering and Nanotechnology, Vol.26, No. 1, pp.7-14, 2002.

[18]. Lecture notes Module 9- non conventional machining, Version 2 ME, IIT Kharagpur http://www.nptel.ac.in.

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