IN-SITU MEASUREMENT OF ELECTRODE WEAR DURING EDM DRILLING USING VISION SYSTEM

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ABSTRACT: Machine vision system is an image-based technology used to perform automatic inspection and analysis such as process control and robot guidance. The aim for this project is to develop a fully automated electrode wear detection system in EDM by using machine vision system and apply this system in detecting electrode wear in EDM. This project was conducted using DSLR camera as monitoring device. The electrode undergo hole making process with a depth of 10 mm, 20 mm, 30 mm, 40 mm, and 50 mm to observe the electrode condition. The image of the electrode will be remotely captured from the laptop and then will undergo image processing process using Matlab software to calculate and determine the electrode wear. The output of this project will show the images of the electrode wear and its wear value. Findings from the project showed that this system is suitable and applicable in EDM super drill machine to monitor the tool condition.

KEYWORDS: *Electrode Wear; Vision System; DSLR; EDM; Power Drill*

1.0 INTRODUCTION

Electrical discharge machining (EDM) is a non-conventional method of machining that have been developed in 1940 and widely used to manufacture aerospace and automotive parts and components [1]. The Basic of EDM was notice first in 1700 and prime usage of arc welding in 1881 by Meritens [2]. This technique grown popular since 1970. Classification of EDM can be done by determining its electrode shape;

machine-feature shaped electrode for die sinking EDM, wire for wire cutting EDM and round, hollow tube for EDM drilling [3 - 4]. The application of EDM technology is wide being employed in tool, die and mold manufacturing industries, for machining of heat treated tool steels and advanced materials (super alloys, ceramics, and metal matrix composites) that hard high exactitude, complicated shapes and high surface end, however polyurethane foam was cut successfully using wire electrical discharge machining (WEDM) process by Azhari [5]. Typical machining technique is usually supported the material removal using tool material more durable than the work material and frequently uneconomical to be manufactured [5]. To achieve high productivity and to control the quality of the product, the EDM parameters should be optimized. However, the event of electrode wear is unavoidable and extremely basic since anode disintegrated and influences the profundity and state of a microstructure.

At the point when a smaller scale round and hollow cathode is utilized for EDM boring or processing, the state of the device anode quickly changes amid machining. Electrode wears happen both toward the end and in favor of the apparatus cathode and are communicated as front wear and corner wear, separately. Front wear causes mistakes in the electrode length and in this manner adds to inadequate profundity of a small scale opening in miniaturized scale EDM, especially to drill. Corner wear prompts adjusted edges of the device cathode and in this manner bringing about geometrical mistake of a microstructure in EDM processing. For turning process the used of nitrogen is efficient in reducing wear of tool [6]. Keeping in mind the end goal to take care of the apparatus wear issue and also enhance the machining precision in EDM, numerous methodologies including device wear expectation, detecting, demonstrating, and pay have been displayed [7]. Electrode wear rate was calculated by measuring the average amount of the electrode eroded and the machining time [8 - 9]. Comparing the weight of the electrode is used to measure the wear [10] however it is difficult to weight the electrode during the process. Small camera is used to monitor during the process [11 - 12]. Thermal camera is applied to measure the temperature during the hot forming [13]. While machine vision system is employed in inspection of define defects on flexible printed circuit (FPC) [14]. Stereo microscope was used to obtain results for kerf width [15]. A robust visual inspection system utilize camera as inspection tools in NDT method for corrosion inspection is also developed [16]. Several CCD cameras is installed to observe the deformation behavior of punch, die and specimen during a micro deep drawing process [17]. The progression in the field of picture handling have prompted fast improvements in the picture preparing procedure and machine vision system have empowered direct cathode wear estimation to be refined in the field of EDM.As to this, this research was done to develop an automated tool conditioning monitoring system using machine vision system to detect electrode wear in EDM.

2.0 EXPERIMENTAL

The process consists of using a precision tubular tool electrode (usually brass or copper) mounted into the drill chuck located on the "Z" axis and held in location on top of the workpiece by the ceramic guide. The top of the workpiece is located and the drilling depth is set. The electrode rotation is turned on and the deionized water solution, which is pressurized between 50 and 100 kg/cm2, flushed through the tube to remove machining debris.

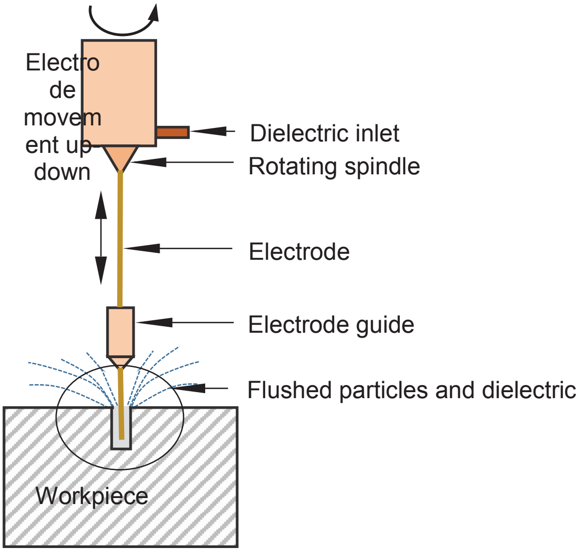

Figure 1: EDM Drilling

The power supply parameters are set-which commonly consist of on-time, off-time, peak current and amount of capacitance. At this time, the discharge is turned on to start the drilling cycle. At the top of the drilling cycle, the discharge is turned off and therefore the "Z" axis is retracted on top of the workpiece. NC computerized system allowing large numbers of holes to be precisely located. Figure 1 showed the process of EDM. The general setup for the experiment are illustrated in Figure 2. The camera with the support of the tripod were placed in front of the machine and the laptop for data acquisition were placed on the right side of the camera. The laptop and the camera are connected through USB cable where the camera will be remotely control from the laptop to capture image of the electrode.

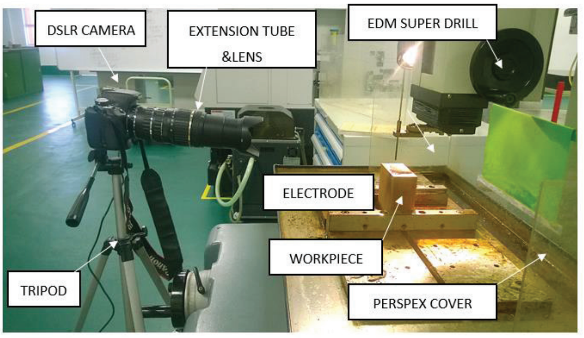

Figure 2: Equipment Setup for Wear Detection of Electrode

In this project, the machine used for this project is Joemars JM528D EDM super drill machine with specification as shown in Table 1 and machine vision system was applied on this machine to monitor and calculate data of the electrode wear. This machine is used to drill hard materials, such as hardened steel in the range of Ø 0.2 mm to Ø 3.0 mm. The camera used for the monitoring system is commercial DSLR model Canon EOS 600D. The specification of the camera are presented in Table 2.

Table 1: JM528D EDM Super Drill Specification

Item	Unit	JM528D
Machine Type	-	Vertical
Work table size	mm	600 X 300
X,Y axis travel	mm	350 X 250
Z Ram servo travel	mm	345
W axis	mm	200
Die electric	-	Distilled water
Max. electrode length	mm	400
Electrode size	mm	Ø 0.2 - Ø 3.0

Since the diameter of the electrode are small (Ø0.2 mm – Ø3.0 mm), a regular lens cannot focus on the electrode to captured a detail image of the wear on the electrode. To solve this, an extension tube is added to lens mounting which turns the lens into macro lens and this will magnify the image of the wear as the focus of the lens towards electrode become closer. In conducting this project, the main software used is Matlab version R2015a. This software contained image processing toolbox which is a powerful toolbox with an inclusive set of algorithms, functions and apps for image processing supports wide range image types. Through this toolbox, image processing such as image analysis and enhancement could be done to analyze the wear of the electrode form the image captured from the camera. The electrode selected for this research is Brass. The main advantages of brass are that it is easily available and can be readily machined. It is usually used for tubular electrodes specialized small hole EDM drilling machine where high wear is acceptable. The properties of the brass electrode are shown in Table 3.

Table 2: Canon EOS 600D Specification

Parameter	Dimension
Image Sensor	CMOS
Effective Pixel	18.0 Megapixel
Effective Sensor Size	22.3 x 14.9 mm
ISO range	100-6400,expandable to ISO 12,800
Autofocus	9 point(1 cross-type)
Shutter Speed	1/4000 sec – 30 sec, bulb
Max. Burst rate	3.7 fps
Max. Image Resolution	5184 x 3456 pixel
Max. Video Resolution	1920 x 1080 @ 24/25/30fps
A/V Output	HDMI
USB connection	USB 2.0

Table 3: Properties of Brass Electrode

Properties	Unit	Description
Specific gravity	g/cm^3	8.5
Melting range	°C	900-915
Thermal conductivity	W/m K	110
Specific heat	J/kg K	380
Thermal expansion coefficient	1 / °C	18.7×10^{-6}
Electrical conductivity	Ω^{-1} / m	15.9×10^{6}
Electrical resistivity	Ω m	6.3×10^{-8}

The workpiece material will be used in this project is AISI P20 pre hardened steel. It has a great feature towards wear and corrosion after thermally hardened through proper heat treatment and commonly used to produce plastic injection molds. The chemical composition, mechanical properties of the material and machining parameters are presented in Tables 4, 5 and 6 respectively. All parameter shown in table 6 are automatically controlled by the machine.

Table 4: Composition of AISI P20 pre Hardened Steel

C	Cr	Si	P	Mo	V	Mn
0.3%	1.1%	0.3%	0.015%	0.55%	0.08%	0.015%

Table 5: Physical Properties of P20 Pre Hardened Steel

Density (kg/m3)	7850
Melting Temperature (K)	1753
Specific heat (J/kg K)	420+0.504T (T in ^{0}C)
Thermal Conductivity (W/m K)	41.5
Hardness	~30 HRC

EDM drilling operations were incidentally intruded, and the electrode will be pulled up to a fixed position where the machine vision system worked legitimately for direct sensing. 3 work pieces were used for each experiment. The flow of the process is illustrated in Figure 3. To capture the image of the electrode wear, the hole making process need to be interrupted for a while and the electrode will be pulled up. Later the image of the electrode will be captured and transferred to the laptop for image processing.

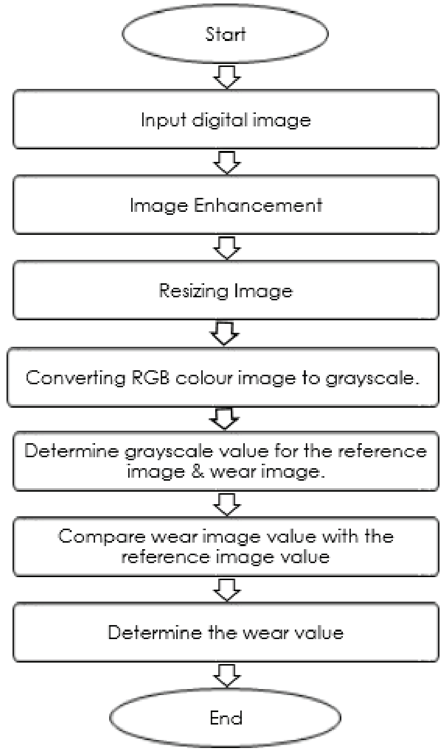

Figure 3: Image Processing Flow Chart

Table 6: Machining Parameter

Parameters	Values
Electrode diameter (mm)	3.0
Current(A)	8
On-time(μs)	18
Off-time(μs)	4
Gap (V)	2
Duty factor (%)	10-90
Servo rate (mm/sec)	2.5
Water pressure (kg/cm2)	30
Spindle speed (rpm)	100
Dielectric fluid	Distilled water

3.0 RESULTS AND DISCUSSION

Figures 4-7 show the RGB image and the grayscale image of the electrode starting from the initial condition (Figure 4) to electrode condition after drilling at 50 mm depth (Figure 7). Same electrodes are used for continuous assessment. At least 3 trials were done for each experiment

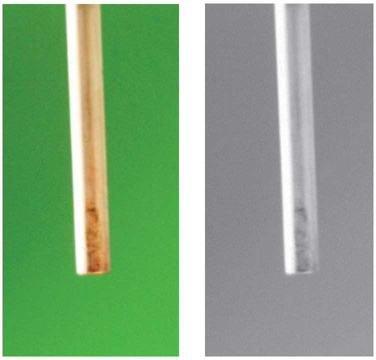

Figure 4: Reference Image

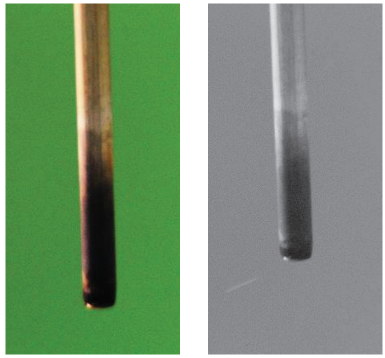

Figure 5: After 10mm Drilling

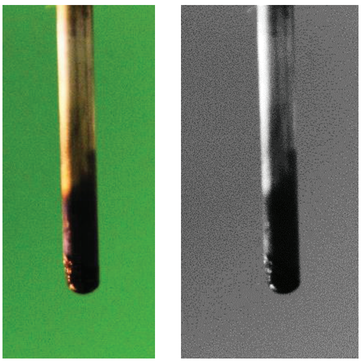

Figure 6: After 20mm Drilling

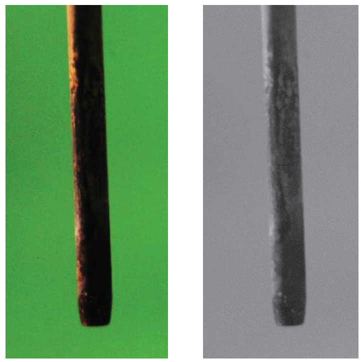

Figure 7: After 50mm Drilling

It can be seen from the images of electrode listed, how the tip of the electrode change after drilling certain depth. By using image processing tool from Matlab, the percentage of the wear can be calculated and determined.

To calculate the percentage of the electrode wear, firstly the RGB image will undergo image enhancement. This is to remove unwanted noise which could causes inaccuracy in the result later on. After removing noises, the RGB images (on the left side in Figures; Figure 4 to 7), will be converted to grayscale images (right side Figures; Figure 4 to 7). The value of the grayscale image will be translated and shown in excel data form and saved. These data will later be calculated using 'SUM' function in Matlab and the grayscale value of the images are obtained. To calculate the wear percentage of the electrode, the formula in Equation (1) will be used. Note that, the image parameters (grayscale value) is play a significant role.

Electrode wear percentage

$$\frac{|R - W|}{W} \times 100\% \qquad (1)$$

where

R= reference image grayscale value.

W=wear image grayscale value.

Figure 8 shows the percentage of wear against the depth of drill. From there, it is shown that as the depth become deeper, the grayscale value of the wear images become lowered compare to reference image. Below will show the relation between the depth of drill and wear percentage in a graph so that, the relation between them can be observed clearly.

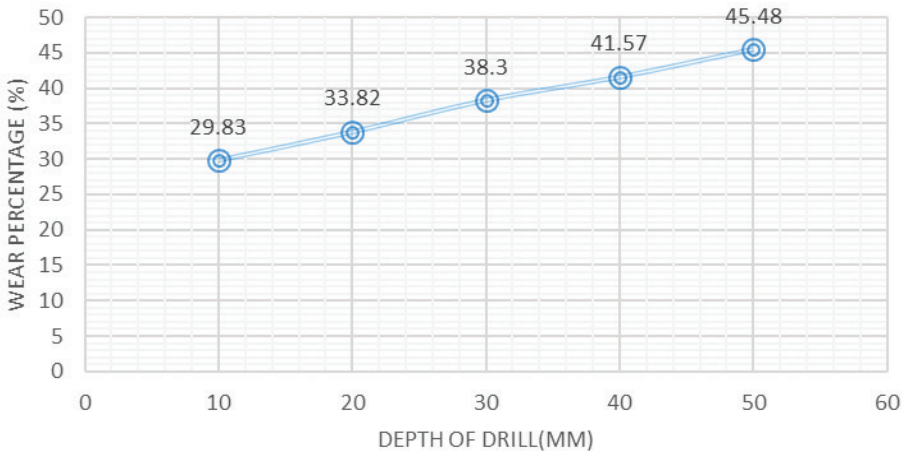

Figure 8: Graph of Wear Percentage vs Depth of Drill

As the depth of drill become deeper, the wear percentage of the electrode become higher and the increment of the wear percentage from 10mm to 30mm by average is 4.235% while from 30mm to 50mm by average is 3.59%.

Wear of the electrode will have a significant affect in the quality of the product as well as the machining time. In bigger environment, this wear can affect production time of a product thus increases the manufacturing cost of a product and also causing the production become inefficient. Among the objective of this study is to implement this machine vision system in EDM super drill and among the target for this implementation is to alert machinist on when to change the tool and thus save much time and cost.

Figure 9 shows the relation between wear percentage (%) and it effect on time taken to drill the holes depth. The wear percentage increases as the depth of drill increases. That is the same with the time. As the wear higher, the time taken become longer. This can be seen clearly in Figure 10.

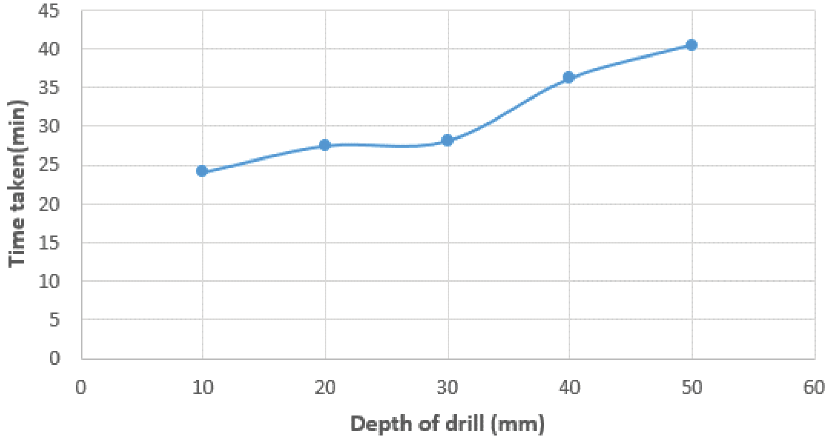

Figure 9: Graph of Time Taken vs Depth of Drill

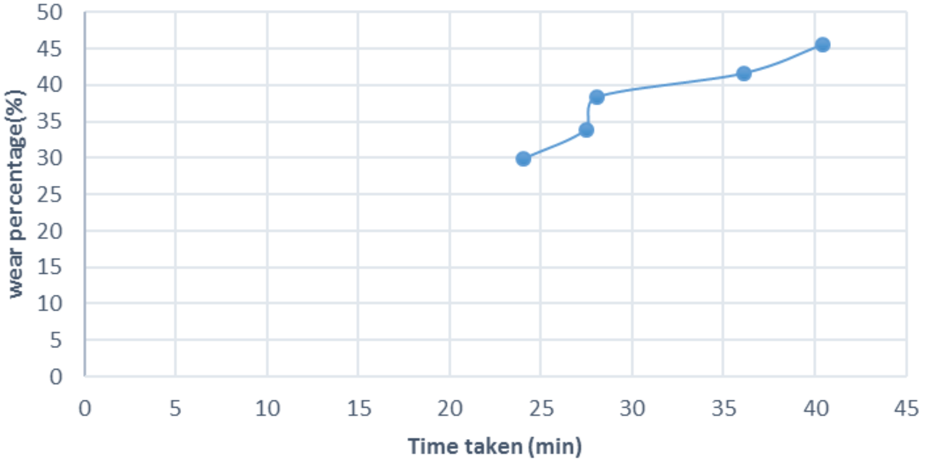

Figure 10: Graph of Wear Percentage vs Time Taken

4.0 CONCLUSION

It can be concluded from this project the machine vision system can be implemented in EDM super drill machine. It is a reliable method to monitor the electrode conditions.

ACKNOWLEDGMENTS

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