

Effect of magnetic polarity on surface roughness during magnetic field assisted EDM of tool steel

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Abstract. Electrical discharge machining (EDM) is one of the non-traditional machining techniques where the process offers wide range of parameters manipulation and machining applications. However, surface roughness, material removal rate, electrode wear and operation costs were among the topmost issue within this technique. Alteration of magnetic device around machining area offers exciting output to be investigated and the effects of magnetic polarity on EDM remain unacquainted. The aim of this research is to investigate the effect of magnetic polarity on surface roughness during magnetic field assisted electrical discharge machining (MFAEDM) on tool steel material (AISI 420 mod.) using graphite electrode. A Magnet with a force of 18 Tesla was applied to the EDM process at selected parameters. The sparks under magnetic field assisted EDM produced better surface finish than the normal conventional EDM process. At the presence of high magnetic field, the spark produced was squeezed and discharge craters generated on the machined surface was tiny and shallow. Correct magnetic polarity combination of MFAEDM process is highly useful to attain a high efficiency machining and improved quality of surface finish to meet the demand of modern industrial applications.

1. Introduction

The electrical discharge machining (EDM) is a process of metal removal from a conducting material by a repetitive spark discharge between tool and work piece separated by a small spark gap immersed in dielectric fluid. The tool moves toward workpiece at a desired gap distance to initiate ionization process when electric current is established between both. A continuous and scattered outburst spark from the tool create small craters on material surface[1]. Machinability of EDM on certain materials depends on suitability of the selected tools and parameters because these factors are going to determine the output characteristics such as surface roughness, electrode wear and material removal rate. Peak current is among the most important parameter in EDM machining. This parameter is measured in amperage. In EDM roughing process, some higher currents normally are selected because of greater material removal rate but it will give poor surface finish and high tool wear. The current will flow into the system and voltage will increases until it creates an ionization path within the dielectric. As the current is flowing, the voltage will drop and stabilize the working gap level[2]. Another essential set up in EDM is sparking distance. In EDM processes the value of voltage prefixed determines the width of the spark gap between the leading edge of the electrode and the workpiece.



Low small gap width between workpiece and the electrode makes the machining debris from EDM process is difficult to remove out. The excessive debris from EDM machining suspended within the dielectric fluid would accumulate in the machining gap tend to induce abnormal electrical discharge, so the stability of EDM progress would be disturbed.

Several authors have introduced magnetic fields in EDM to transport ferro-magnetic material debris through the gap and to improve debris circulation. The first study was done in 1978 by De Bruijnet al.[3]. Other researchers also agreed that the resultant magnetic force was efficient in transporting debris out from the machining area during material removal process[4-7]. Magnetic field assisted EDM would facilitate the stability of machining progress that occurs in between the spark gap. The machining performance would be improved by expelling debris from the machining gap fast and easily. The experimental results suggested that the magnetic field assisted EDM process was one of the most promising processes that can be regarded as an attractive and excellent alternative for surface finishing process[8].

The general direction for the magnetic flux flow is from the north (N) to the south (S) pole of the magnet. In addition, these magnetic lines form closed loops that leave at the north pole of the magnet and enter at the south pole. Magnetic poles are always in pairs. However, magnetic flux does not actually flow from the north to the south pole or flow anywhere for that matter as magnetic flux is a static region around a magnet in which the magnetic force exists. In other words, magnetic flux does not flow or move it is just there and is not influenced by gravity[9]. Researchers also had introduced and invented new EDM machining processes such as dry EDM and near dry EDM, powder mixed EDM, and ultrasonic vibrations assisted EDM to solve EDM machining limitations. In this study, magnetic field assisted EDM (MFAEDM) process with selected magnetic polarity was developed to explore the effects of magnetic polarity on EDM machining characteristics. Excellent combination of EDM machining techniques and parameters would satisfy the surface finish of machined components for better industrial application.

2. Experimental method

The Charmilles Roboform22 EDM machine was used in this investigation to conduct a series experiments in this work. A set of permanent magnetic (magnetic flux density: 18T) device was attached to the EDM machine. The experimental setup was used to explore the performance of the MFAEDM on Stavax ESR tool steel (AISI 420 mod.) in kerosene dielectric by using graphite electrode. The schematic diagram of the experimental setup is shown in Figure 1. The two magnets were arranged to face each other to achieve the desired magnetic polarity. The workpiece material was tool steel (AISI 420 mod.) which is widely used in die and mould manufacturing industry for the core component. The workpiece specimen was milled into cube shape of 30mm X 30mm X 30 mm. The specimen has mass elemental composition of Fe – 84.32%, C [10]– 0.38%, Si – 0.9%, V – 0.3%, Cr – 13.6% and Mn – 0.5% [11]. Cylindrical graphite was selected as the electrode material. The electrode size used to conduct electrical discharge was 25mm in diameter and 40mm length to accommodate machining depth of cut and clamping purpose. The essential properties of graphite electrode are summarized in table 2. In addition, kerosene was adopted as a dielectric fluid in this study. The kerosene in the EDM container serves several functions such as to initiate sparks, as an insulator between the tool and the workpiece, prevent shorting and acts as a coolant.

The experiments were carried out in normal condition as the datum result and MFAEDM were conducted for different magnet polarity. The permanent magnets were clamped side by side to the stavax ESR samples so that the same pole facing each other (N-N) to achieve the repulsive magnetic force. In another set up difference pole combination (N-S) was arranged to create an attractive magnetic force. The machining output such as material removal rate, MRR (g/min), electrode wear rate, EWR(g/min), and surface roughness (Ra/mm) were adopted to evaluate the effects of machining parameters on the MFAEDM and conventional EDM processes. For every experiment, the electrode and the samples material were weighed before and after removal process to calculate MRR and EWR. The samples of EDM will undergo for surface roughness measurement to evaluate surface quality of the machined surface. The value of surface roughness was obtained by averaging four measurements

on different positions of each machining condition. Then, those samples were part-off and the cross-section surfaces were well-polished as a preparation for cross section observation. The surface then etched in a combination of HCL and picric for eight minutes before undergoing for SEM observation.

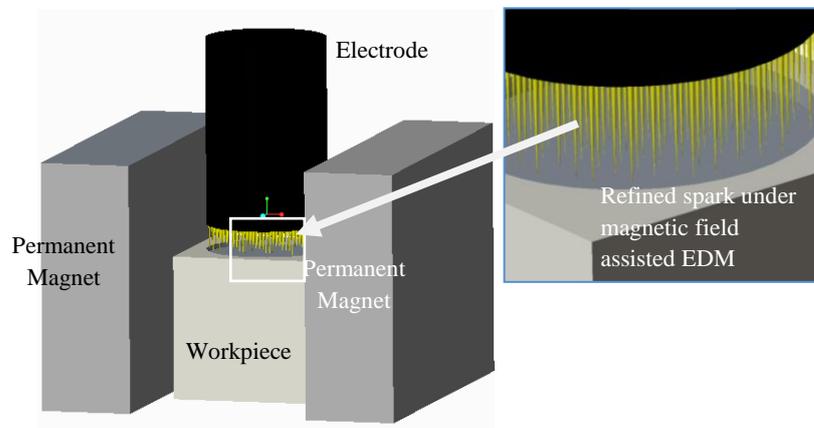


Figure 1. Schematic diagram of MFAEDM.

3. Result and discussion

In general, EDM machining with or without magnetic field assistance produces a higher surface roughness at a higher value of peak current as shown in Figure 2. This is expected since higher discharge current results in higher thermal loading on the both electrode and workpiece thus removing a higher amount of materials. As a result, surface finish becomes rougher at a higher peak current.

In case of magnetic field assistance, the magnetic field drives the magnetic lines according to the arrangement and combination of magnets. Machining debris is attracted to the attached magnet near the cutting area. As a result, the machining area will be cleared from debris thus reducing disturbance for subsequent cutting cycles. Therefore, a smoother surface can be expected during MFAEDM process. Figure 2 shows the effect of magnetic polarity and peak current of surface roughness of Stavax ESR tool steel. It is clear that the surface roughness is reduced with the use magnetic field assistance by about 16% and 20% respectively for peak current of 8A and 24 A. Magnetic field assistance restricts the spread of plasma thus increasing the energy at the machining area[4]. Consequently, the material removal process is improved with the combination of enhanced spark energy and magnetic force.

It can be seen from Figure 2 also, the polarity combination of N-S produces better surface finish as compared to N-N magnet arrangement. The surface roughness was reduced as much as 10% for peak current of 8 A and 8% for peak current of 24 A. This circumstance has a connection to the magnetic force direction and magnetic field lines where the sparks are affected by the magnetic field [12]. In N-S magnet arrangement, the magnetic field acting perpendicular to the electrode [13]. The resultant magnetic field which is in tangential action improves those disengage spinning electrons and ions from their core atom thus increasing ionization process [6]. The process increases the plasma pressure and plasma density. The plasma pressure acts as a piston on the melt pool that exerts downward force [4].

Furthermore, it is evident that N-S MFAEDM produces better surface quality than N-N MFAEDM as shown in Figure 3. It can be seen that crater and recast layers were formed on the machined surface as a result of continuous melting and evaporation processes during the machining. The valleys produced from the spark in normal EDM (Figure 3 (a)) are deeper and wider than N-N MFAEDM (Figure 3 (b)). N-S MFAEDM produces craters which are shallow and small as shown in Figure 3 (c) thus resulting in better surface quality.

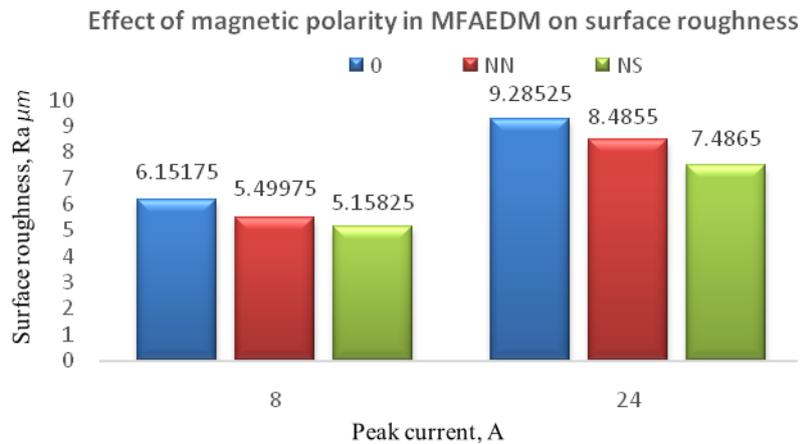


Figure 2. Effect of magnetic polarity and peak current on surface roughness.

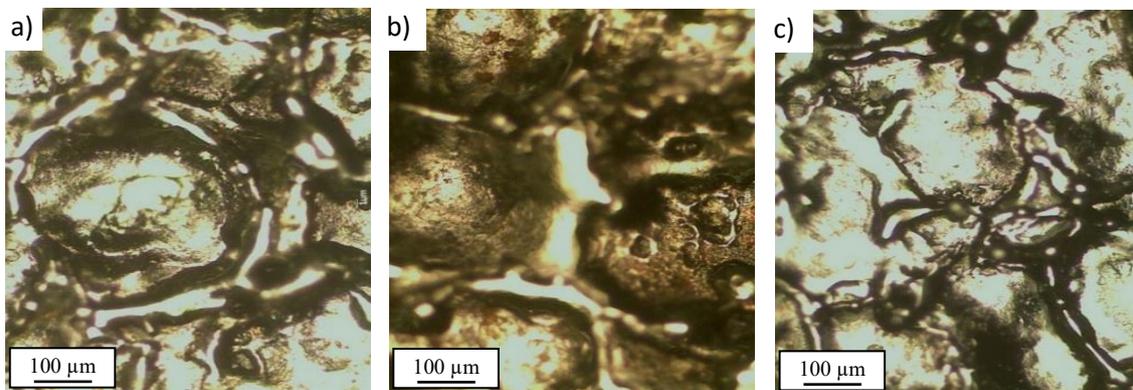


Figure 3. Surface microstructure of (a) normal EDM, (b) N-N MFAEDM and (c) N-S MFAEDM at 200X magnification of optical microscope (24A, 50 μs).

In N-N magnetic pole combination, there is a neutral spot in the middle of the magnetic flux line which is contrary to N-S magnetic pole combination. At this neutral spot, the resultant magnetic force is zero[14]. So, the plasma pressure for ionization process in N-N polarity is lower than N-S polarity. Whilst in N-S MFAEDM, the magnetic force acts tangential to the plasma channel. It is known that N-S MFAEDM process increases the ionization process thus the formation of plasma channel is accelerated. In the meantime, the spark produced was squeezed resulting in tiny and shallow craters on the machined surface thus reducing its roughness[15]. Therefore, N-S magnetic polarity combination minimizes the ignition delay time and maximizes the spark intensity thus improving the surface quality of EDM samples.

4. Conclusions

As a conclusion, it is obvious that magnetic field assisted EDM provides better quality of machined surfaces. In term of magnetic polarity application, it was found that it is best to use north to south combination of magnetic poles. Therefore, a correct magnetic polarity combination of MFAEDM process is highly useful to attain a high efficiency machining and improved quality of surface finish to meet the demand of modern industrial applications.

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