J. Appl. Environ. Biol. Sci., 7(11)30-37, 2017
© 2017, TextRoad Publication

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Improvement of Material Removal Rate and Surface Roughness for Steel Grade 760 Using Magnetic Field Assisted Al_2O_3 Powder-Mixed EDM

R. N. H. R. Ismail, A. A. Khan, A. N. M. Karim

Manufacturing and Materials Engineering Department, International Islamic University Malaysia, Kuala Lumpur, Malaysia

Received: June 4, 2017
Accepted: August 20, 2017

ABSTRACT

Electrical Discharge Machining (EDM) is one of unconventional machining process that attracts people in mould making industries because of its numerous advantages. However, debris clogged in the machining gap affect EDM performance. Recent research agreed that EDM with the assistance of magnetic field could counter the debris clogged problem and powder-mixed EDM has also proved to improve the surface qualities of the workpiece. Therefore, this research combined those two EDM-based hybrid machining together which is known as magnetic field assisted powder-mixed EDM. It used Aluminium Oxide (Al_2O_3) as the powder mixed in the dielectric fluid of EDM and permanent cylindrical-type magnet to have the magnetic field influences. Steel grade 760 was used as the workpiece as it is one of the common steel used in mould cavity making and copper was used as the electrode. Three input parameters which are peak current (I_p), pulse on-time (T_{on}), and powder concentration (P_{conc}) was selected. The purposes of this research are to improve the material removal rate and also the surface hardness of the workpiece.
KEYWORDS: Powder, Magnet, Electrical Discharge Machining.

INTRODUCTION

Recent years have seen a rapid development of manufacturing techniques in order to fit the demand in industry. This phenomena may arise from the evolution of technology that has put tremendous pressure on manufacturing industries to come out of the arena of conventional machining processes.

Therefore, unconventional machining processes have been developed to meet so many challenges of machining including high hardness and strength of the workpiece, high toughness of the workpiece, when the workpiece is too slender to withstand machining forces, complexity of the shape of the parts, special surface finish required, temperature rise during processes and development of residual stresses. Electrical Discharge Machining (EDM) is one of those unconventional machining processes that have attracted much interest in manufacturing industries.

Electrical Discharge Machining (EDM)

EDM is a thermoelectric process in which heat energy of a spark is used to remove material from the workpiece [2]. It has unique capabilities in eroding every material which is conductive and also producing complex 3D cavities regardless of the workpiece hardness, strength and microstructure [1]. It does not make direct contact between the electrode and the workpiece, thus the resulting machining force is quite small [4]. It also eliminates mechanical stresses and vibration problems during machining. Therefore, it plays an important role in the manufacture of mould, die, automotive, aerospace and surgical components.

Powder-Mixed EDM (PMEDM)

Powder mixed EDM (PMEDM) is a process in which a suitable conductive powder is mixed into the dielectric. When a voltage of suitable magnitude is applied across the electrodes, the powder fills up the spark gap and bridges the gap between the tool electrode and the workpiece. Due to this bridging, the gap voltage and insulating strength of dielectric fluid reduce and discharge frequency increases which results in faster erosion. The powder particle enlarges the plasma channel which ultimately results in uniform distribution of spark [2].

In this research, it is essential to know which powder has no reaction with magnetic field so that it will not be attracted to the magnet and deposited evenly on workpiece surface. It is stated that the magnetization of a material is dependence on susceptibility and magnetic field strength. The powder that will be used in this research work is

Corresponding Author: R. N. H. R. Ismail, Manufacturing and Materials Engineering Department, International Islamic University Malaysia, Kuala Lumpur, Malaysia, E-mail:nurulhidayah_128@yahoo.com

Aluminium Oxide (Al_2O_3) andTable 1 shows the powder properties of Al_2O_3 used and the magnetic susceptibility [5].

Table 1: Properties of Al_2O_3 powder used

	Grade	Magnetic Susceptibility (10^{-6} c.g.s. Units)	Average Particle Size (Micron)	Purity
Al_2O_3 powder	PK-41	-37.0	30-45	99.9

Magnetic Field Assisted EDM

One of the common issues related to EDM is improving the performance of EDM through improving the material removal rate (MRR) of the workpiece, decreasing the tool wear rate (TWR) and improving the surface finish of the machined surface. A non-uniform and unstable discharge process may result from the presence of left over debris due to short pulse off-time and/or insufficient flushing [3].

It is known in recent research that one of the methods that have been used to improve the performance of EDM is using the application of external magnetic field where the magnet/s was/were placed around the discharge channel and machining gap during EDM. In [2] state that the EDM based hybrid machining process (EHMP) had drawn a conclusion regarding magnetic force assisted EDM, stating that there was only a few research done in magnetic force assisted EDM, electrical discharge abrasive grinding and laser assisted EDM compared to electrochemical discharge machining and ultrasonic assisted EDM as shown in Figure 1.

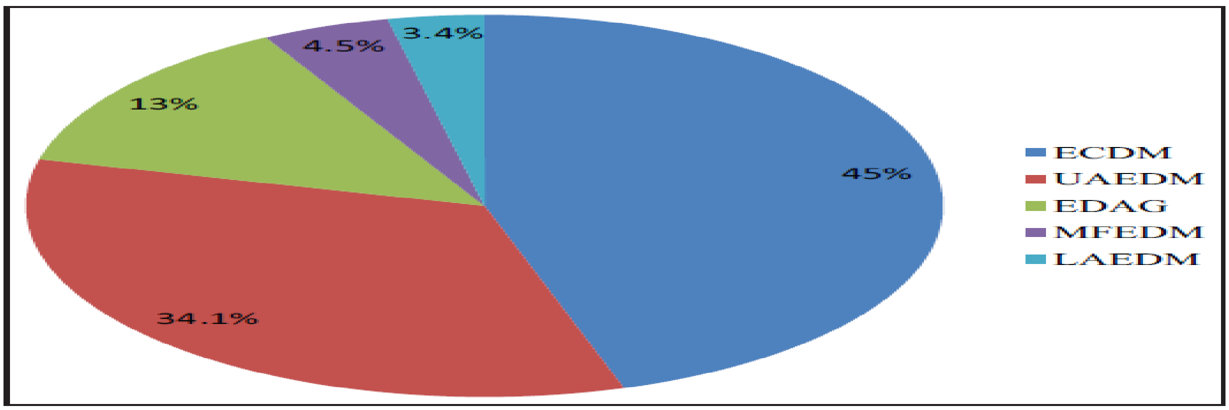


Figure 1: Percentage distribution of works carried out on different EHMP (Note: ECDM = electrochemical discharge machining, UAEDM = ultrasonic-assisted electrical discharge machining, EDAG = electrical discharge abrasive grinding, MFEDM: magnetic force-assisted EDM, LAEDM = laser-assisted EDM)

Hence, it is essential to do some research works in the area of magnetic field assisted EDM and to contribute some findings in hybrid EDM.

METHODOLOGY

The debris particles clogged in the machining gap during EDM process may affect the performance of EDM since they caused uncontrolled secondary sparking and disturb the electrical discharges. It can damage the workpiece and reduce machining efficiency. Thus, we used magnetic field to assist the PMEDM process in improving the debris removal mechanism and altering the surface qualities of the workpiece steel grade 760 which is usually used in mould cavity making. In this research, the influence of magnetic field assisted PMEDM process parameters on MRR and surface roughness were investigated. Briefly, the experimental details outlined as follows:

1. Selecting the workpiece, tool, powder and process parameters to be investigated and specifying their appropriate levels. The three chosen input parameters are peak current (I_p), pulse on-time (T_{on}) and powder concentration (P_{conc}). The ranges of $I_p$and T_{on} are taken from machine manual book, while the range for $P_{conc}$is taken from previous research. The workpiece used in this research is steel grade 760 and the electrode is copper and their compositions are shown in Table 2 and Table 3 respectively. Dielectric used is kerosene.

Table 2: Workpiece Chemical Composition (%)

C	Si	Mn	P	S	Cr	Ni	Cu
0.550	0.280	0.840	0.015	0.008	0.030	0.040	0.090

Table 3: Electrode Chemical Composition (%)

Cu	Sn	Pb	Fe	Ni	Sb	As
99.985	<0.0005	0.005	<0.0005	0.0017	0.0018	<0.0005
P	Cd	Zn	Bi	Te	Ag	
0.0034	<0.0005	0.0014	<0.0005	<0.0005	0.0016	

2. Experimental design planning-The two level three full factorial Response Surface Methodology (RSM) was adopted to design the experiments. Table 4 shows the design of experiment for this research using Design Expert 9.0.6 software. There are 8 runs for each set of experiment. There are 3 sets of experiment for this research and thus total of 24 runs of PMEDM were conducted.

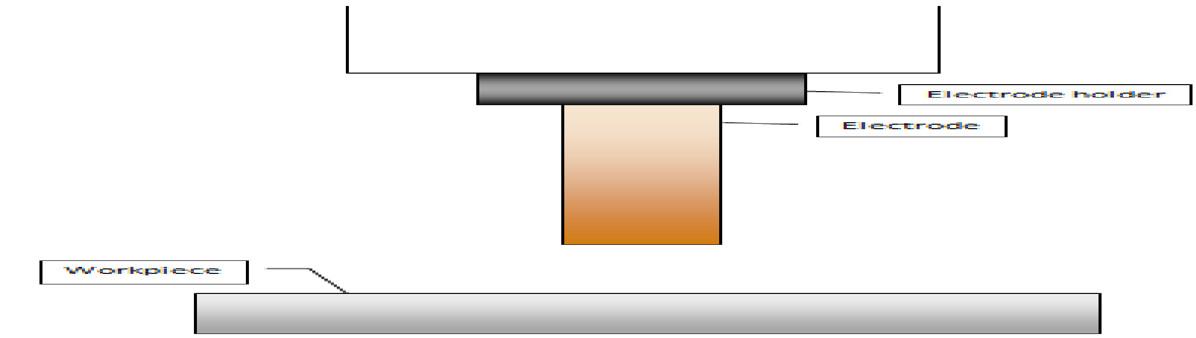
Table 4: Design of experiment

Run	I_p(A)	T_{on}(μs)	P_{conc}(g/L)
1	6.5	6.0	8
2	1.5	6.0	4
3	1.5	10.5	4
4	6.5	10.5	8
5	6.5	6.0	4
6	6.5	10.5	4
7	1.5	10.5	8
8	1.5	6.0	8

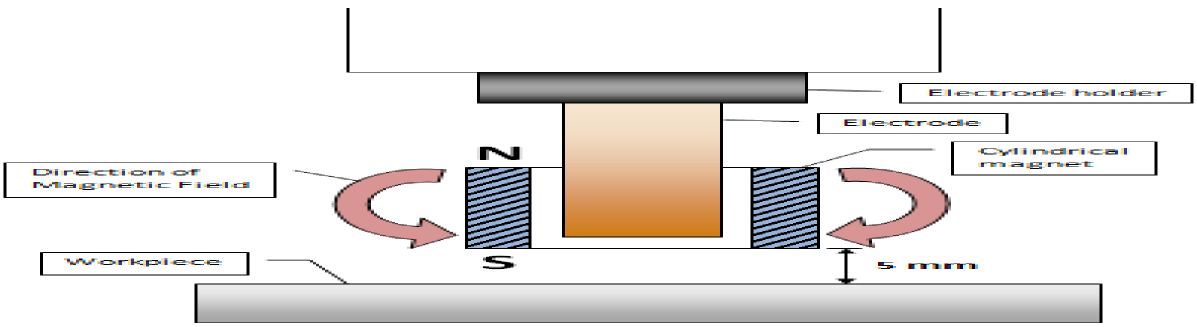
3. Preparation of materials and experimental setup. Figure 2 shows the experimental setup for this research.

Figure 2: Experimental setup

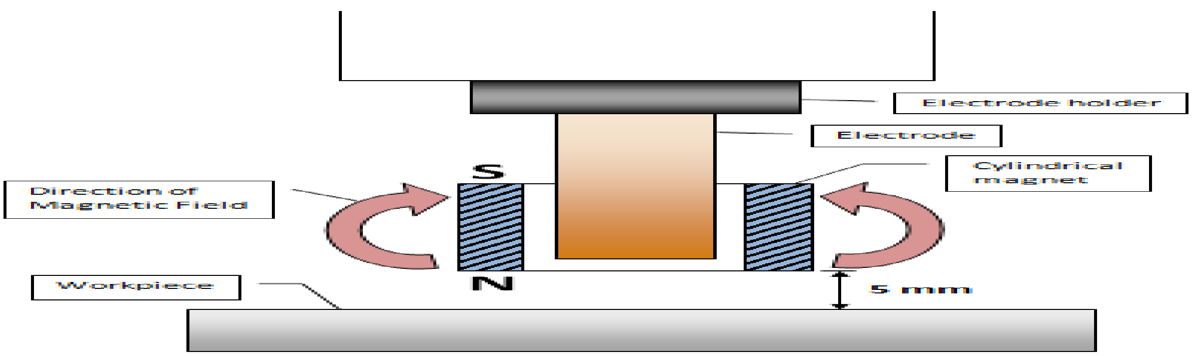
4. Experimental procedures which includes the machining of Al_2O_3-PMEDM using Mitsubishi EX22 die-sinking EDM machine with three different magnetic field configurations namely no magnetic field, downward magnetic field and upward magnetic field which denoted as Case A, Case B and Case C respectively. The schematic diagram of those 3 magnetic field configuration are shown in Figure 3. MRR and TWR measurement with AND-HF3000G digital weighing scale and calculation. Surface roughness measurement with Mitutoyo SURFTEST SV.500 surface measuring instrument. Surface hardness measurement with Mitutoyo ARK-600 Rockwell hardness tester.
5. Data processing, data analysis and software application with ANOVA which includes mathematical model formulation of MRR, TWR, surface roughness and surface hardness for three different magnetic field configurations of Al_2O_3-PMEDM and multiple responses optimization to obtain the best values of MRR and surface roughness.



Case A: No magnetic field



Case B: Downward magnetic field



Case C: Upward magnetic field

Figure 3: Schematic diagram of three magnetic field configurations

RESULTS AND DISCUSSION

The mathematical models for MRR, TWR, surface roughness and surface hardness for each case were developed by using Design Expert 9.0.6 software in terms of coded factors as presented in Table 5.

Table 5: Developed mathematical models (Note: X_1-peak current, X_2-pulse on-time, X_3-powder concentration)

MRR	**Case A: + 0.22 + 0.21* X_1 + 0.061*X_2 + 6.250E-004*C**
	Case B: + 0.22 + 0.22* X_1 + 0.062*X_2 + 6.250E-004*C
	Case C: + 0.22 + 0.21* X_1 + 0.062*X_2 + 1.500E-003*X_3
Surface Roughness	Case A: + 10.94 + 7.37* X_1 + 2.85*X_2 - 0.027*X_3
	Case B: + 9.25 + 6.58* X^1 + 2.86*X_2 - 0.071*C
	Case C: + 8.98 + 6.65* X_1 + 3.24*X_2 + 0.80*X_3

It is clear from the developed mathematical models for MRR, the main effect of all the individual parameters are positive. Surface roughness models reveals that all of individual parameters have positive impact except for powder concentration in Case A and Case B. The software analysis also provides graphs to help interpret the model selected and the 3D surface graphs MRR shown in Figure 4-6, and 3D surface graphs for surface roughness shown in Figure 7-9 for all three cases with actual factor (C: powder concentration = 6.00 g/L).

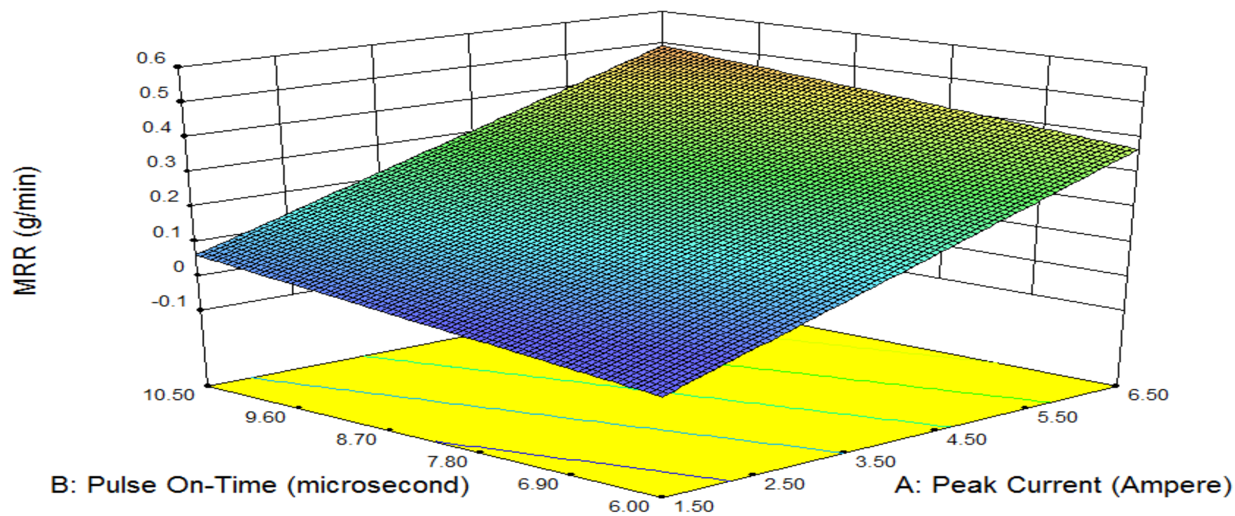


Figure 4: MRR (no magnetic field)

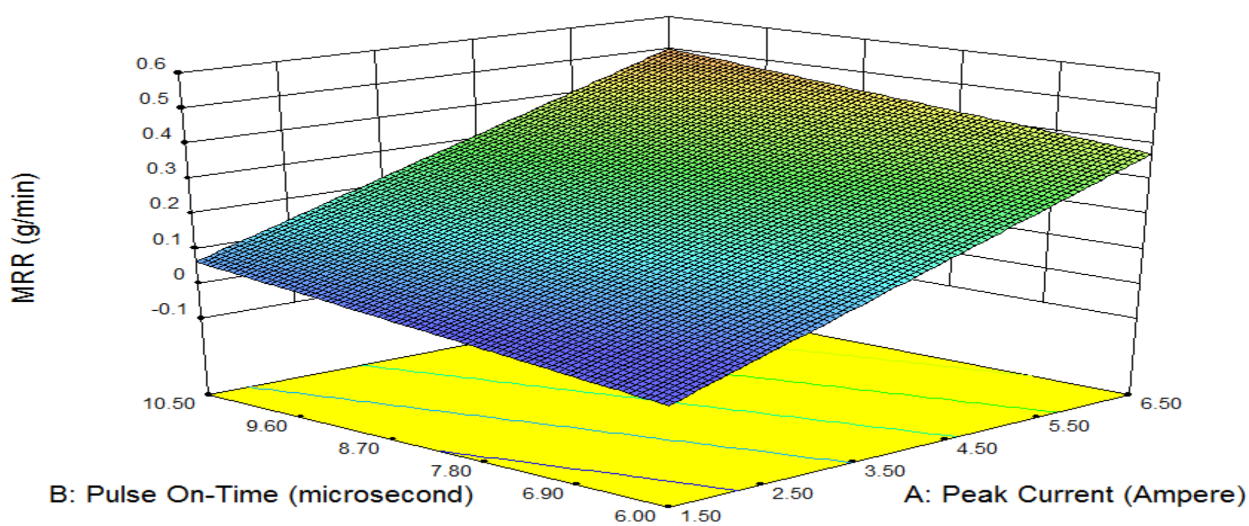


Figure 5: MRR (downward magnetic field)

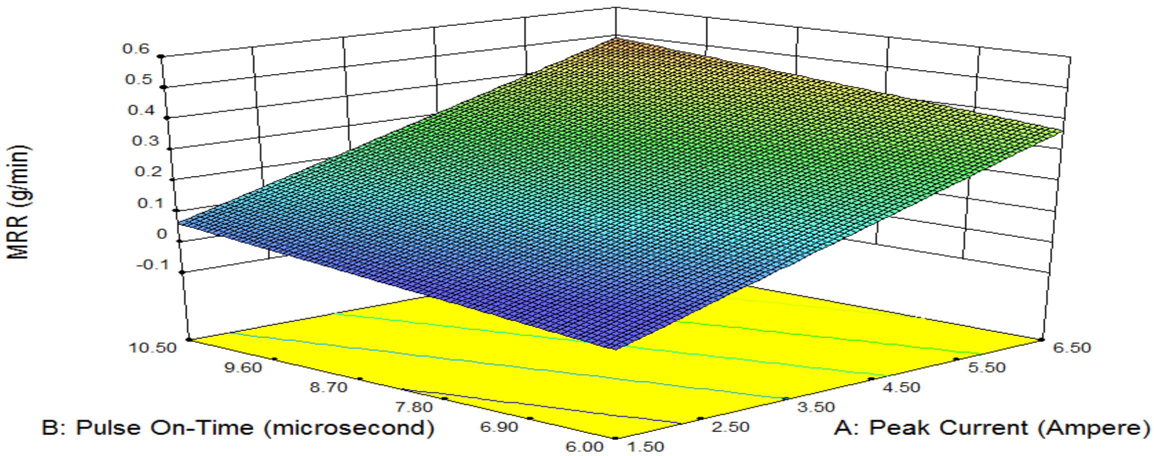


Figure 6: MRR (upward magnetic field)

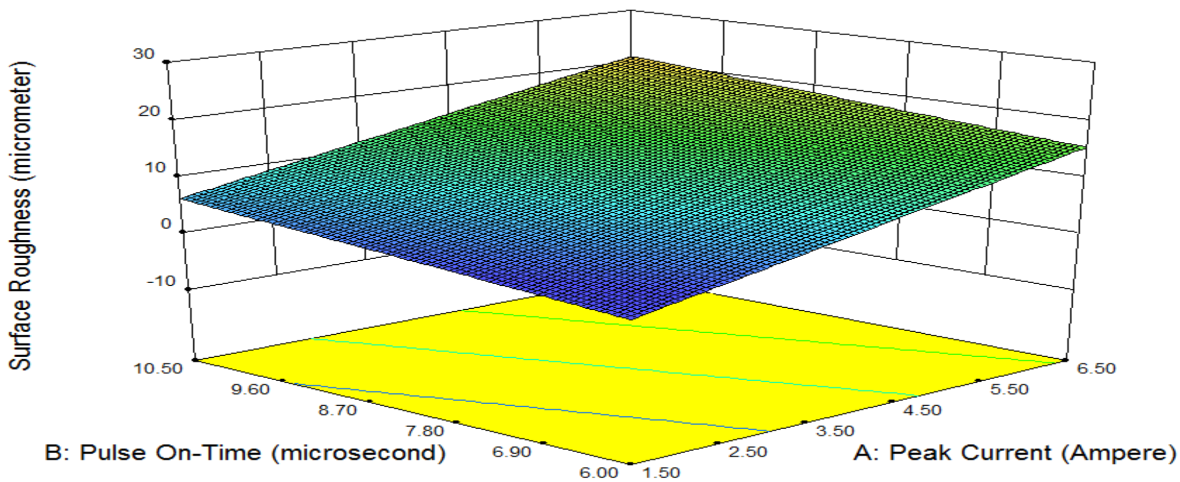


Figure 7: Surface roughness (no magnetic field)

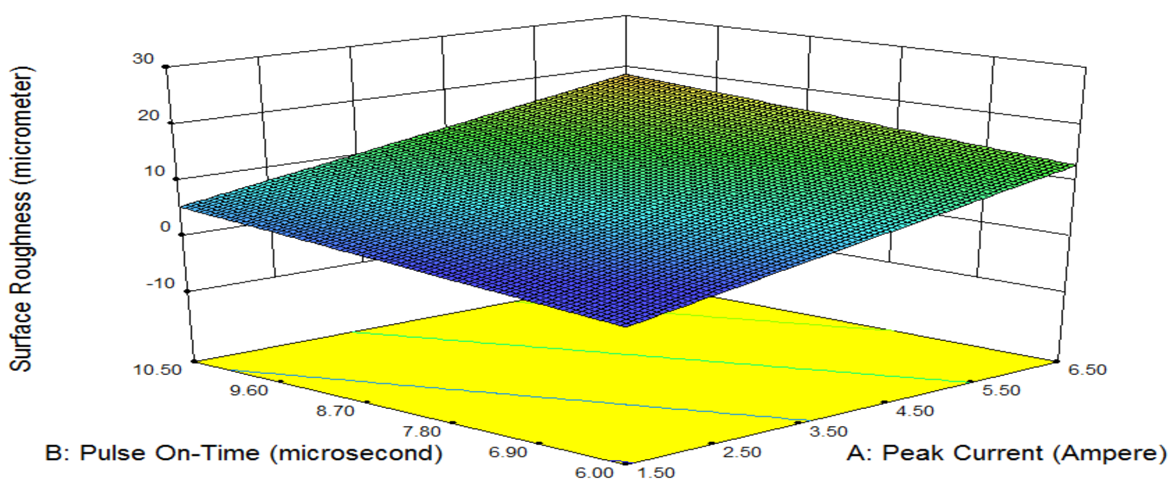


Figure 8: Surface roughness (downward magnetic field)

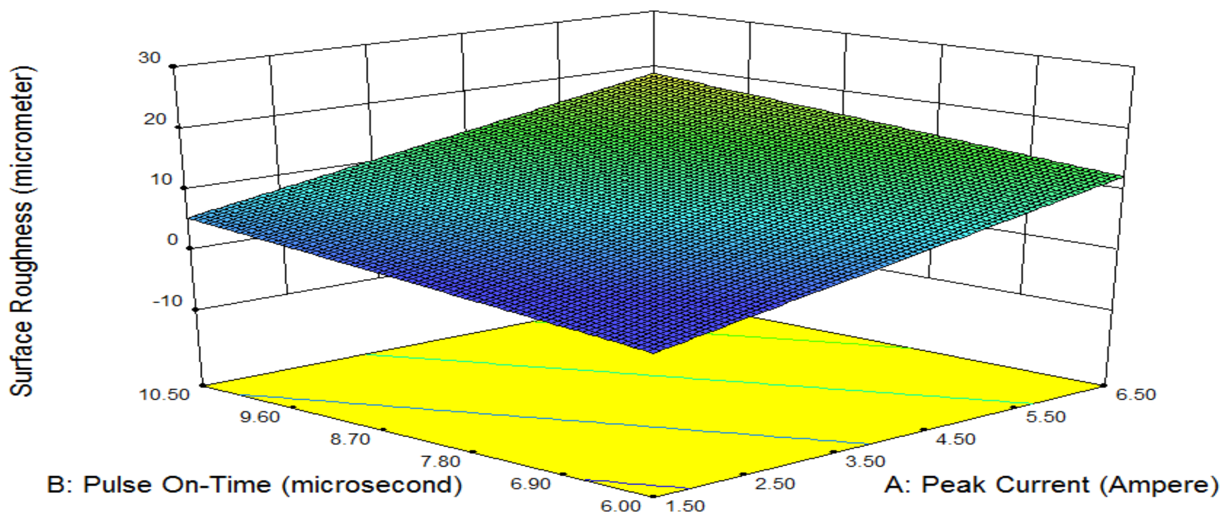


Figure 9: Surface roughness (upward magnetic field)

In this study, the desirability was constructed based on the range of actual values obtained. Only one solution is being selected, which is the most desired set of condition to give the optimum outcome for both factors and responses is also presented in Table 4.

Table 4: Optimization

Case	I_p(A)	T_{on}(µs)	P_{con}(g/L)	MRR (g/min)	Surface Roughness (µm)
A	2.714	6.574	6.712	0.062	5.015
B	3.117	6.419	7.672	0.095	4.539
C	2.967	6.343	4.140	0.075	2.743

From the table, it shows that whenever the magnetic field is applied, the Al_2O_3-PMEDM machining performance were improved. As can be seen, the optimization of the three factors were in the range based on the design of experiment; peak current (1.5A-6.5A), pulse on-time (6.0µs-10.5µs), powder concentration (4.0g/L-8.0g/L). The MRR for Cases A, Band C is 0.062g/min, 0.095g/min and 0.075g/min respectively. Average surface roughness of the workpiece machined surface is minimized in Case C (2.743µm) with significant difference with cases A (5.015µm) and B (4.539µm). However, further investigations are required to confirm such results. At this stage, what is certain is that without any changes in the machining setup, the magnetic field assisted approach can yield significant improvement in material removal rate and surface roughness of steel grade 760 in Al_2O_3-PMEDM process.

CONCLUSION

In this research, a magnetic field-assisted approach was utilized to improve the PMEDM performance. The experimental results and the developed mathematical models indicate that the input process parameters affect the responses. The application of cylindrical magnet contributed to higher machining performance of PMEDM in terms of MRR and surface roughness as can be seen in Case B and Case C compared to Case A where no magnetic field was applied. The magnetic field assisted PMEDM in improving the debris removal mechanism when Lorentz force drives ions into motion and thus induced a more effective circulation in the narrow gap between the tool and the workpiece steel grade 760 which is usually used in mould cavity making. Other types of powders and magnet type can also be used as a baseline for future comparisons and improvements. The magnitude and location of the magnetic field also merit further investigation to achieve a better enhancement effect in machining performance of PMEDM.

REFERENCES

1. Assarzadeh, S. andM. Ghoreishi, 2013. A Dual Response Surface-Desirability Approach to Process Modeling and Optimization of Al_2O_3 Powder-Mixed Electrical Discharge Machining (PMEDM) Parameters. International Journal of Advance Manufacturing Technology, 64 (9): 1459-1477.
2. Pankaj, K.S. and K.D. Avanish, 2013. Electrical Discharge Machining-Based Hybrid Machining Processes: A Review. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 228(6): 799-825.
3. Rajurkar, K.P., M.M. Sundaram and A.P. Malshe, 2013. Review of Electrochemical and Electrodischarge Machining. Procedia CIRP, 6: 13-26.
4. Rina, C., K.G. Susanta and C. Shankar, 2013. A Study on the Multi-Response Optimization of EDM Processes. International Journal Machining and Machinability of Materials, 13 (1): 91-109.
5. Reade International Corporation, 2016. Reade advanced materials. Retrieved from http://www.reade.com/.