A review on magnetic field assisted micro machining

Renjith R¹ and Lijo Paul²*

¹Post Graduate Student, ²Associate Professor,
Dept. of Mechanical Engg., St. Joseph’s College of Engineering and Technology,
Palai, Kerala, India, 686579
E-mail*: lijo.paul@gmail.com

Abstract. Micromachining has developed in the last few decades with precision as primary aim. Many conventional and non-conventional processes are developed with precision in the range of micro level. Hybrid machining processes are developed in non-conventional machining area by combining the principles of basic machining process. In the current paper a review is carried out on Magnetic field assisted micro machining with thrust on EDM, ECM and ECDM machining process. The effect magnetic force during the machining has improved the machining output responses in terms on MRR and surface qualities.

Keywords: ECDM, Magnetic Field Assisted Machining, MRR, ECM, EDM

1. Introduction

In the last few decades, the need of advanced materials increased due to their unique metallurgical properties such as Super alloys, Composites, Ceramics. These properties have been developed to meet the demand of extreme applications such as in aerospace, automotive and biomedical industries etc. These advanced materials are harder, tougher, less heat sensitive and more resistant to corrosion and fatigue. Advanced materials are being widely used these days not only in the aerospace but also in defense and automotive. Therefore, the machining of difficult-to-machine materials is a predominant issue in the field of micromachining. Micromachining plays a vital role in miniaturization of parts used in aerospace (cooling holes in jet turbines blades), micro holes in fuel injection system of automotive, micro probes and micro needle for bio-medical application etc. Micromachining has great advantages in machining of hard materials in non-conventional machining as well as in conventional machining such as micro-mechanical milling, chemical etching, and micro-detonation of striking arc machining. In the current paper a literature review is
conducted focusing on the micro machining process such as Micro-EDM and Micro-ECDM and the enhancement of machining properties by the introduction of a magnetic field.

2. Magnetic Field Assisted EDM

The micro machining processes paved the way for advanced machining operations. The use of magnetic field assisted micro machining was introduced in 2008 [1]. The author has reported that an introduction of magnetic field in the conventional EDM will eliminate limitations and enhance the material properties. The major limitation in conventional EDM process is the settlement of debris between the machining gaps. A rotating magnetic field is introduced in a conventional EDM machine is converted. The rotating magnetic field was created by placing a rotating magnet below the workpiece, which can be rotated about 1200 rpm by the assistance of an electric motor. The workpiece material that used in this experiment was SKD 61 steel. In this research, the stability of the magnetic force-assisted EDM was determined by the analysis of discharge waveforms, and the machining characteristics such as Material Removal Rate (MRR), EWR, and surface integrities were explored. The results reveals that the MRR of the magnetic force-assisted EDM was increased nearly three times compared with that of conventional EDM, and the surface roughness was also finer than that of conventional EDM. However, the EWR was slightly higher than that of conventional EDM. The magnetic force-assisted EDM revealed the potentiality of expelling the debris and improving the machining efficiency. The MRR of the magnetic force-assisted EDM added-on with peak current and pulse duration, and the MRR reached a peak value at 20 A peak current and 350 ms pulse duration. The author recount that surface cracks became more obvious in the conventional EDM than that in the magnetic force-assisted EDM. Since the magnetic force-assisted EDM could facilitate the expulsion of machining debris to diminish the probability of abnormal electrical discharge, so the surface cracks were probably less on the machined surface.

Y.C. Lin and H.S Lee [2] reported that the magnetic field assisted EDM will exaggerate the conventional machining processes. He has optimized the machining parameters in magnetic field assisted EDM with Taguchi method. The effects of magnetic force on EDM machining characteristics were scrutinized in their work. The proposed work was adopted an L18 orthogonal array based on Taguchi method to conduct a series of experiments and statistically evaluated the experimental data by analysis of variance (ANOVA). In order to determine the EDM machining characteristics such as material removal rate (MRR) and surface roughness (SR), the main machining parameters such as machining polarity (P), peak current (Ip), pulse duration (p), high-voltage auxiliary current (IH), no-load voltage (V) and servo reference voltage (Sv) were chosen. The benefits of magnetic force assisted EDM were confirmed from the analysis of discharge waveforms and from the micrograph observation of surface integrity. The experimental result reveals that the magnetic force assisted EDM has a higher MRR, a lower relative electrode wear ratio (REWR), and a smaller SR as compared with standard EDM. In addition, the substantial machining parameters, and the optimal combination levels of machining parameters associated with MRR as well as SR were also discussed. In addition to it the work emphasis on the contribution provided by magnetic force assisted EDM in expelling machining debris attain a high efficiency and high quality of surface integrity to meet the demand of modern industrial applications.

The use of magnetic field in the dry EDM was studied by S. Joshi et al. [3]. They have investigated a hybrid dry EDM process in a pulsating magnetic field for improving process performance. In this cogitation, the pulsating magnetic field is applied tangential to the electric field, for increasing the movement of electrons and degree of ionization in the plasma. Experiments with parametric variations showed that this hybrid approach leads to productivity improvement by 130% and zero tool wear as compared to the dry EDM process without the magnetic field. The improvement in surface quality is illustrated by scanning electron microscopy.

Govindan et al.[4] also modeled the effect of magnetic field in dry EDM with single spark in magnetic field assisted dry EDM. They reported that the Material Removal Rate (MRR) increased about 130% as compared to conventional dry EDM. He found that presence of Lorentz force developed due to the presence of magnetic field. An investigation was made by them over 100 single- discharges in dry and
liquid EDM with and without magnetic field with variation in machining parameters such as varying magnetic field, varying voltage, varying current, varying pulse on time & bi-pulse current. They reported that the magnetic field increased the depth and crater diameter about 80% in the case of dry EDM.

The optimization of magnetic field assisted EDM using ACO algorithm was proposed by R. Teimouri and H. Baseri [5]. They have supported the result proposed by Y.C.Lin and H.S Lee [1] in using a rotating magnetic field for better fleshing of the debris from the machining zone. Based on experimental observations two Adaptive Neuro-Fuzzy Inference System (ANFIS) models have been designed to correlate the EDM parameters to MRR and surface roughness (SR). They proposed the continuous ant colony optimization technique to select the best process parameters. Experimental trials divided into three main regimes of low energy, the middle energy and the high energy. Results showed that the CACO technique which used the ANFIS models as objective and constrain functions can successfully optimize the input conditions of the magnetic field assisted rotary EDM process.

A new variety magnetic field assisted EDM was proposed recently by Khan et al. [6]. They mixed a powder of along with the magnetic field. A permanent cylindrical magnet is used in this experiment and the workpiece used is steel grade 760. The electrode used was copper and peak current, pulse-on-time and powder concentration.

Brains et al. [7] conducted experiments in Magnetic field assisted EDM with machining parameters such as magnetic field intensity, peak current, duration of pulse on/off, tool electrode material and SiC% distribution. They adopted the Taguchi method for optimization and the analysis of results shows that increase in magnetic field, increase in peak current and increase in pulse-on-time increases the MRR.

3. Magnetic Assisted ECM
A novel concentrated magnetic field-assisted electrochemical machining (ECM) technology is proposed by L. Tang & W. M. Gan [8], to machine complex cavity with high efficiency and good precision. An ECM clamping apparatus with concentrated magnetic field, periodic magnetic field, and no magnetic field was described. The magnetic field simulation was implemented. Comparing the results of the concentrated magnetic field to the periodic magnetic field, the magnetic field intensity of the former is elevated by 9.8% than the last-mentioned. Under the experimental conditions of 12% NaNO3, 14-V voltage, 0.8-MPa electrolyte pressure, temperature 32 ºC, cathode feed rate 0.9 mm/min, initial machining gap 0.1 mm, and the S-03 special stainless steel work piece material, the experiments with concentrated magnetic field, periodic magnetic field, and no magnetic field were carried out. The results show that the magnetic field strength was increased by 16.7% in the concentrated magnetic field than in the periodic magnetic field. Through a sectioning test, the precision in the concentrated magnetic field is increased by 33.3% compared with no magnetic circuit and increased by 14.8% compared with the periodic magnetic field.

4. Magnetic Assisted ECDM
C.P. Cheng [9] studied the importance of magnetic field in hybrid micro machining process, Electro Chemical Discharge Machining (ECDM) on non-conducting material. They have reported about the lack of electrolyte flow at the narrow gap between the tool and workpiece in conventional ECDM. They have found the formation of a magneto hydrodynamic convection in the magnetic field assisted ECDM and the enhancement of electrolyte circulation. They have reported application of Lorentz force in inducing charged ions to form magneto hydro dynamic force and there by enhance the circulation by forcing electrolyte. They insisted that the magneto hydrodynamic convection induced by the magnetic field plays the key role in the enhancement of electrolyte circulation in the micro hole. They also reported the formation of a gas film by the coalescence of gas bubbles that evolved at tool surface and argues that the gas film quality influence the discharge performance. This gas film quality is the dominant factor that determines the machine quality such as geometric accuracy, material removal rate and surface integrity. The magnetic field was produced by introducing a ring magnet of Nd-Fe-B on the electrode and the work piece used is Pyrex glass. The results reveal that the gas film quality was enhanced and the maximum stability of gas film occurred at a higher voltage.
5. CONCLUSION
The micromachining process is discussed in the current paper with thrust on non-conventional machining process. The area of consideration includes the magnetic field assistance in micro machining process which includes EDM, ECM and ECDM process. The study shows that the limitations in micro machining can be eliminated by the application of a magnetic field. The results show that the presence of magnetic field enhances the MRR and the presence of Lorentz force enhances the machining operations.

REFERENCE
[1] Yan-Cherng Lin, Ho-Shiun Lee, 2008 Machining characteristics of magnetic force-assisted EDM
[2] Cherng Lina, Yuan-Feng Chena, Der-An Wang, Ho-Shiun Leeb, 2009, Optimization of machining parameters in magnetic force assisted EDM based on Taguchi method.
[3] S. Joshi, P. Govindan, A. Malshe, K. Rajurkar, 2011, Experimental characterization of dry EDM performed in a pulsating magnetic field
[4] P. Govindan, A. Gupta, Suhas S. Joshi a, Ajay Malsheb, K.P. Rajurkar, 2013, Single-spark analysis of removal phenomenon in magnetic field assisted dry
[5] R. Teimouri, H. Baseri, 2014, Optimization of magnetic field assisted EDM using the continuous ACO algorithm
[6] R. N. H. R. Ismail, A. A. Khan, A. N. M. Karim, 2017, Improvement of Material Removal Rate and Surface Roughness for Steel Grade 760 Using Magnetic Field Assisted Al2O3 Powder-Mixed EDM
[7] Preetkanwal Singh Bains, Sarabjeet Singh Sidhu & H. S. Payal, 2017, An investigation of magnetic-field-assisted EDM of composites
[8] L. Tang & W. M. Gan, 2013, Experiment and simulation study on concentrated magnetic field-assisted ECM S-03 special stainless steel complex cavity
[9] Chih-Ping Cheng, Kun-Ling Wu, Chao-Chuang Mai, Yu-Shan Hsu and Biing-Hwa Yan, 2010, Magnetic field-assisted electrochemical discharge machining.