Significant complications declining usage of Electrical Discharge Machining process

Gurpreet Singh Matharou1 and Basanta Kumar Bhuyan1

1 Department of Automobile Engineering, Manav Rachna International Institute of Research and Studies, Faridabad, India
gsmatharou1@gmail.com

Abstract. In the present paper, an effort has been laid down to develop a framework for the micro EDM (µ EDM) in today’s industrial environment. The µ EDM has shown considerable involvement in ceramic industries where workpiece needs to be machined in micro sizes. µ-EDM owing to stronger surface quality and higher precision is a futuristic machining process for building up micro tools and alternative micro components. However, there are several complications that demand to be discussed before µ-EDM can be dealt with as a decisive technique and it can carry out its performance. This investigation includes of the EDM system scheduling and electrode wear issues. Particular consideration has been offered to aspects and methods critically varying the efficiency involving positioning approaches during grinding of electrode and new µ-EDM operations.

1. Introduction
The EDM process is noticeable since 1770-74 when Dr. Joseph Priestly (an English Scientist) invented the electrical flow erosive effects. In 1943 EDM process was discovered by Dr. B.R. Lazarenko. They had created Makarenko circuit which is of interest in current scenario also [1]. There was a complication with inadequate electrode which had been amended in 1960’s by treatment of pulse and solid-state generators in extension to revolving systems. In 1980’s first CNC based EDM was started in USA [2]. Nowadays EDM uses approaches based on non-traditional energy origins such as electrical (electrons and ions), sound and light, mechanical and synthetic etc [3]. With technology improvements and advancement in materials, fresh and harder to structure materials such as composite components, ceramics, and alternative metallic objects finds space in aerospace, industrial and fundamental systems. Machining of such tough substances becomes useless with classical practices of machining and thus EDM process for material removal becomes significant [4]. Electrical discharge machining (EDM) as a non-traditional material removal process employed in aerospace, surgical and automotive region in charge to develop dies, punches, moulds, precision parts etc [5]. This process can handle all electrically conductive components regardless of their firmness, hardness, shape and proportion. EDM has showed usage in mould and tools manufacture setups such as drilling of pieces and in producing turbine parts for airline industries, e.g., in tool creating setups the material discharged from a metal slab to create drill sections or in the specific cutting of substances such as drilling narrow holes or openings that are lesser than 0.05-0.06 inches [6]. Another convenience of EDM over conventional machining methods is that with EDM, it is viable to cut pre-hardened steel in complicated outlines or cavities without the inclination to mitigate the pre-seasoned steel by conventional heat treatment methods, and later re-harden it [7]. It has likewise demonstrated profitable and compelling in the machining of hard, high quality, and temperature opposition of conductive
material [8]. It assumes an excellent job in the production of least-cost items with increasingly dependable quality affirmation. Micro EDM is an important type of EDM and has shown lots of applications in ceramics industry [9].

Many researchers had worked on different combinations of workpiece-electrodes, different dielectrics combinations, different machining input variables to ascertain the effects on different responses. Mukhopadhyay et al [10] had attempted micro drill operation on μ-EDM of Monel K-500 sheet using a Cu electrode with deionized water as a dielectric, to access the effects of current (Ip), pulse on time (Ton), working time (WT), Al powder concentration on circularity. Response surface methodology (RSM) used for model development. The optimum circularity value of 0.976 suggested for input parameter values Ip=1.2A, WT=1.8 sec, and Al concentration of 3.33 gm/liter. Mallick et al [11] had attempted micro electrochemical discharge machining (μECDM) on glass (silica) using a stainless-steel electrode (straight and curved) with NaOH and KOH electrolyte solution. The study was an attempt to find out the effect of voltage (v), electrolyte concentration (EC) and tool shapes (straight and curved) on material removal rate (MRR), the width of cut (WOC), heat affected zone (H.A.Z), and surface roughness (Ra). They reported an increase in the H.A.Z, MRR, and WOC with an increase in V for both types of electrolytes and tool shapes. Lowest HAZ reported at 50V, 10%wt KOH electrolyte with curve tool. They suggested optimum condition of V= 50V, 20 % wt. of KOH, and advocated straight shape electrode for micro channel cutting on glass (silica) material. Tiwary et al [12] had studied the μ-EDM operation of Ti-6AL-4V with a brass electrode, to access the effect of Ip, powder type (Cu, Ni, Co) mixed in de-ionized water and powder concentration (2,4,6 g/L) on MRR, electrode wear rate (EWR), taper, and overcut(oc). Dielectric with powder mixed in de-ionized water offers the best MRR, and Normal de-ionized water dielectric provides better EWR, taper, and OC. They suggested cobalt mixed de-ionized water at 4 g/L with Ip 1.5A to be an optimized setting for machining the titanium composite using PCA and overall principal component index (OPCI). Jahan et al [13] investigated during μ-EDM of micro holes on NiTi Shape memory alloy (SMA) and Ti-6Al-4V, the Ra at the center point and edges are reported to be dissimilar, they suggested the phenomenon was due to an advanced concentration of spark at the center in relation to the sides. The electrode reported to turn out to be hemispherical and tapered, resulting in a higher spark at the center. Due to the formation of oxide layers, microhardness has reported to increase in both the materials. Better Ra has been reported in NiTi (SMA). Singh et al [14] had attempted μ-EDM of two different Al2O3 composites with conducting fillers in the form of multi-walled carbon nanotubes (MWCNT) in 2.5 and 5 vol. % of concentration. High MRR has been reported in composite with 5 vol. % of MWCNT. A 60% enhancement in MRR (both composites) at tool rotation of 750 rpm. Ra has reported to reduce by 20%. With an increase in tool rotation speed, less recast layer deposition at edges had been reported. Better machining characteristics of brass tool reported, in comparison with copper and WC. The research study focuses on the leading issues of μ-EDM machining and linked causes that needs to be discussed for producing a dependable process that can lead to accurate results. Also, the paper comprises of the μ-EDM investigation area and therefore will offer research subsequent trends.

2. Micro EDM

In μ-EDM, the workpiece (anode) and tool (cathode) are separated by dielectric fluid (kerosene or deionized water) and was fed with a pulsed voltage. Figure 1 illustrates the simplified depiction of μ-EDM. The workpiece and tool are brought closer until the dielectric in the channels plunges down and allows current to move through it causing sparks. The spark intensity can be altered by changing the input parameters of the machine [15]. The μ-EDM offers extensive prospects to generate miniature topographies, micro components and the fabrication of μ electro-mechanical arrangements [16].
The µ-EDM technique employed for manufacture of micro pieces can be segregated under four groups [17]. Wire µ-EDM where an electrode diameter-wire is diminished to about 0.02mm to decrease a conductive work piece. µ-EDM drilling utilizes micro electrodes to drill work piece short pits of diameter 0.035-0.45mm. Die sinking µ-EDM [5] where electrode image is replicated on the work piece with a little overcut. µ-EDM milling where micro electrodes are employed to develop three dimensional cavities by seeking a transfer approach as witnessed in traditional milling [18].

2.1 Process parameters

The specifications in micro-EDM are employed to deal with the behavior measures of the micro-EDM fabricating process. Process parameters are the controllable machining inputs that regulates the environment in which machining is being carried out. Pulse on time (T_{on}) is the period of flow of discharge and is the stage through which the electrode is heated by the strong plasma channel. Pulse off time (T_{off}) shows the period during which nil flow of discharge exists and the dielectric is given time to clear the melted plasma away from the workpiece and restore its insulating properties. Spark gap (Sg) is the distance amongst the electrode and workpiece for respective EDM cycle. Duty factor (\Psi) is a percentage of the pulse interval with reference to the total cycle time. Current (I_p) denotes electrical charges travelling between the tool and workpiece. I_p has a direct influence to the MRR. Voltage (v) can be read across the tool electrode/workpiece gap before the spark current starts to flow. Straight polarity in which the electrode is connected to negative terminal & work-piece to the positive terminal. Reverse polarity is just the reverse [19].

2.2 Response variables

These criteria project the various actions of µ-EDM results. Material removal rate (MRR) & electrode wear rate (EWR) shows the volume of material removed from workpiece & electrode respectively, with reference to time and usually measured in mm³/min. The surface roughness (R_a) displays the surface finish in µm. It is generally measured using profilometer. The overcut (OC) shows the difference between the hole/cavity size and the electrode size [19].

3. Shortcomings of Micro EDM

The µ-EDM offers contactless machining expertise which is applicable for brittle substances machining. The machining process gives very less impact on the workpiece and likewise supports in producing proper microstructures. It offers tolerances of the range of +/- 0.005 [20]. The hardness of the workpiece makes no influence on the machining. It has demonstrated usage in exceedingly hard materials such as nimonic, stellite, tungsten carbide, etc. It likewise presents potential of machining complex shapes under thin-walled environment of micro-level without leaving burrs in it. Fragile and subtle parts can be machined due to a no force process. Despite the capacities achieved even though these processes are not utilized extensively because of the accessibility process and due to non-accuracy of machine tools [21]. The research will concentrate on some issues limiting the operation of µ-EDM and will present positive explanations. This section presents the above discussed operations of µ-EDM and recognizes complex operations. A recent process to handle model is required for product miniaturization. Several issues have turned up because of variation in micro machining requirements.
3.1 Formation of work piece and electrode
For development of minor craters preparation for threading of wire, work piece and electrode formation are a serious trouble. These cracks might have micro diameters with various aspect ratio and relies on the file to be fabricated. In preparation they are made either by Traditional drilling or EDM drilling. The holes positioning efficiency with endorse to the degree expected should be bigger so as to facilitate the practice of automatic threading and to restrict limited circuiting after wiring process. The holes threading on specialized systems of micro wire is exceedingly crucial. In trial of micro die sinking, it demands at least two to three electrodes developed either by EDM or micro milling. There could be chances of misrepresentation and irregular shapes of electrodes geometry. The electrode improvements not merely are costly & time dominating but likewise may produce distinct result since three electrodes may not have identical properties [5]. Trajectory EDM employs a simple shaped pipe, electrode or shaft of diameter between 0.15 and 0.42mm. The conducting electrode is dissipated against an electrode sacrificed in a process specified as grinding of EDM [22].

3.2 Handling of electrodes and its parts
There are several issues with electrode operation and the relevant parts when the direction is to cut down the diameter of the wire. Initially already occurring wire instruments were bought to accept slight diameter wires but they demand reasonable time for arrangement of machine [23]. There is a massive inconvenience for wire establishment as the spool place to nozzle of interweaving is substantial. The brakes productive forces cannot be employed owing to fine wires. This leads to periodic fractures in wire and requires periodic manual intervention [24]. In die sinking of μ-EDM drill or milling, varied designs and machineries can be adopted to uphold handling smaller parts and electrodes. Therefore, sub structures are combined into structures of micro EDM for fabrication on the apparatus and maintaining desired micro electrodes shapes and sizes. WEDG (wire electro discharge grinders) includes identical subsystems are ceramic guides & treating units [25].

3.3 Process Planning
In μ-EDM process strategy is of ultimate relevance and should be thoroughly set down dealing with the miniature size of elements and machined surface tolerances. During the machining process and during preparation stage several mistakes exist pointing to failed results. These mistakes may be because of imperfection equipment and stochastic sparking process [5]. Several papers aim ways of upgrading operation of EDM like the MRR, Rₐ and reduction in EWR. For μ-EDM the criteria of process are nevertheless at the improvement stage and their impacts on achievement measures needs to be formulated. The optimization of specifications is based on investigation of transform to establish the impact of every process variable on the desired machining features [26]. There is reduction of CAM components to support μ-EDM despite the usage of vaster expansion of automation of EDM machines and CNC controller’s etc. Three-dimensional cavities machining operation is challenging since tools path adopted in existing techniques of CAM is complex [27]. The prevailing practice does not allow electrode wear compensation nor assist slice thickness variation or endorse the distinctive orientation of cut with every piece [28].

3.4 Measurement
The micro attributes pertaining to surface finish is not smooth. There are no legitimate processes of surface roughness assessment which is a fundamental quality of micro tooling [29]. Specialized apparatus is instructed to figure out the (HAZ) heat affected zone and (RL) recast layers which have noticeable effect on work piece surface properties [30]. For feature dimensions, evaluation of electrode is instructed to obtain stronger machining in Micro EDM [31].

3.5 Repeatability and accuracy of machine positioning
It is one of the primary fault causes. ISO 230-2-1997 is employed for measuring the veracity & repeatability of μ-EDM with the cooperation of laser interferometer [32]. For machining a micro hole
at a given quantity of arranged electrodes might be adopted therefore the hole position depends on machine position certainty and hence the shape and size of the crater [33].

3.6 Errors in cycle evaluation
The EDM machine processor indicates the signal as brought in through the electrical approach of work piece and electrode through spark [34]. The processor accepts priorities defined to substantiate each signal of machine contact signal and is not chosen continually. Generally, verification of contact signal is drawn every two or five minutes undoubtedly to diminish the machining speed the EDM speed must be lowered as attainable but better enough to bypass stick slip. The voltage exists in between the spindle and table during the stepping cycle. Till contact of electric is made machine drives. The measurement efficiency depends upon the advance of appeal to the work piece surface [35].

3.7 Errors of temperature fluctuation
Owing to variation in room temperature condition, there is variation in work piece and electrode internal grain arrangements and therefore the relative arrange between the whirling head and machine table thereby modifying the covering unit position in reference to machine zero position and electrode. The inequalities can be lowered by emphasizing optimum temperature contained rooms and assuring thermal strength in machine systems [36]. Every EDM machine requires to be justified and setup desires to be maintained for some ambient situations, the assigned fluctuations require to be measured and recognized to diminish electrode and workpiece positional errors [21,26,28].

3.8 Spark gaps
The pulse parameters selection immediately regulates the $R_a$ and MRR desired in traditional EDM. High value of peak current and voltage offers excessive value of MRR in case of tungsten carbide whereas EWR can be lessened by significant value of pulse off time followed by modest values of peak current [37]. In $\mu$-EDM the little spark gap helps in achievements of micro characteristics with less EWR. The specifications of pulse are appointed on the base of surface roughness and on the dressing speed. The rotating electrode must not jolt with the machined surfaces roughness [38].

3.9 Fixtures and Jigs
Ceramic model is the most recognizable material for carrying the WC electrode [39]. Owing to variations in adequate diameter of ceramic guide and electrode, there are chances of electrode tolerance variation. The electrode located within the guide moves to radical positions contributing to peak variation [40].

3.10 Electrode type
The electrodes employed in $\mu$-EDM are extremely basic in shape and during the EDM process are revolving, which accordingly establishes uniform conditions all-round the electrode [41]. These uniform sparking conditions endorse the usage of electrostatic field modelling of the medium between the electrodes. The electric field between the electrodes is interpreted as the electrical force per unit charge [23]. The orientation of the field at a position is described by the orientation of the electric force expended on an effective attempt charge established at that spot [42].

4. Results and Discussions
The review provides an outline of significant complications decreasing usage of $\mu$ EDM and affecting the production. The issues cited in this study can use to work out the process within tolerances as per expectations. When allocating tolerances of handling for $\mu$ EDM entire process situations such as kind of arranging, kind of electrode grinding, and operation extent must be dealt with, since all such exercises may attend to mistakes giving wrong yields which can’t be recognized for investigation purpose. The overall capability of machining relies on a compound affinity between diverse specifications of process and the optimization is built primarily on empirical techniques. The
manufacturing technique handling of μ EDM must utilize stable approaches and innovations with continuous results. The proposed micro milling strategy replaces complicate interpretations of continuing processes with straightforward evaluation of length. This must prepare fresh strategy pleasant to the production & for analysis purpose.

5. Conclusions.
In the existing paper, an effort has been completed to outline the concept of μ EDM in todays industrial environment. The μ EDM has shown considerable involvement in ceramic industries where workpiece needs to be machined in micro sizes. Despite the capacities achieved even though these processes are not utilized extensively because of the accessibility process and due to non-accuracy of machine tools. Other key issues addressed includes development of workpiece and electrode, usage and type of electrode used and different wear ratios. Errors addressed during cycle evaluation, handling issues etc. Without addressing the μ EDM discussed issues, it is not possible for its maximum coverage in micro industries.

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