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A Review on Optimization of Micro EDM Machining Performances

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Abstract- Now these days there is a massive requirement in the production of microstructures by a unconventional method. Micro-EDM (µEDM) is a widely accepted unconventional machining option in which material erosion takes place from work-piece using a sequence of electrical spark. This method is used to manufacture micro-parts with the range of 50 µm -100 µm. This paper studied the optimization of various process parameters namely gap voltage, peak current and pulse duration to attain suitable µEDM performance measures such as Material Removal Rate (MRR), low Electrode Wear (EW) and good surface morphology of the microstructure accepted from µEDM machining process.

Keywords: Micro-EDM, Material Removal Rate, Too Wear , Surface Morphology

I. Introduction

Diver C et al. [1] described that µEDM is a imitative of the EDM process for machining small microstructure. It is a well established process used to produce micro holes in metal utilized for numerous application namely spinner holes, turbine blades cooling channels, and drug delivery orifices. This method is quite similar to EDM process in which material erosion of conductive material takes place using generated spark between two conductive electrodes regardless of its hardness, strength etc. This paper brief study of the several papers represent the effect of process parameters on the machining performance related to µEDM with four headings namely MRR, EW, surface quality as well as microstructure of µEDMed component .

II. Material Removal Rate Mechanism

The MRR is the proportion of the volume (mm^3) of material remove of work-piece to the machining time (min). Minh Dang Nguyen et al. [2] revealed the application of deionized water for µEDM because it offers higher MRR as well as low tool wear than other fluid. On the other hand, higher value of frequency with small pulse interval decrease material erosion. In addition, the µEDMed surface with deionized water shows minor result from material movement because of a smaller amount debris observed in the µEDM machining. Fuzhu Han et al.[3] revealed the comparative use between transistor-type and traditional-type isopulse generator in µEDM. The transistor-type isopulse generator shows more removal rate and machining speed than traditional-type isopulse generator. G. Kibria et al.[4] observed the result of various dielectric namely boron carbide suspended kerosene, deionized water on machining performances during µEDM machining of titanium alloy. The deionized water shows more MRR and TWR than kerosene. Whereas boron carbide-mixed dielectrics shows higher value of MRR, but TWR reduces with kerosene dielectric. The deionized water shows lower white layer thickness on EDMed surface compared to kerosene. The higher value of MRR with the rise of pulse interval with B_4C mixed kerosene as compared to pure kerosene and deionised water because of more spark discharge time. Mohammad Ahsan Habib et al. [5] represented the manufacturing of complicated electrodes for µEDM. For this purpose, In this study, the localized electrochemical deposition (LECD) is used due to its cheap with safety manufacturing process. This electrode is preferred as negative electrode polarity results more MRR than positive tool. On the other hand, tool RWR reduces with this negative tool. In addition, it is save time saving and cost method. Kun Liu et al. [6] demonstrated novel method used in µEDM based on pulse generator. This method is used to machine ceramic composite Si_3N_4-TiN and stainless steel. But the MRR of Si_3N_4-TiN composite is high compared to stainless steel whereas drastically low tool wear is observed.

M. S. Azad et al. [7] optimized process performances of µEDM drilling of titanium alloy based on Taguchi method. The MRR improves with discharge energies. The end wear of electrode is source of errors for assessment of the electrode length. The side wears influence the form of the hole created .The voltage is the most important parameter in µEDM .Muhammad Pervej Jahan et al.[8] studied the improving surface characteristics with graphite nano particles blended in dielectric of µEDM and µEDM milling of cemented tungsten carbide. The presence of this enhance the surface finish, material erosion because of machining of more surface region and reduce the EWR. The powder-mixed µEDM milling offers even and perfect surface because of good flushing condition compared to sinking µEDM. G. Bissacco et al.[9] analysed both work piece and tool wear in µEDM milling of steel. Both the MRR and electrode wear volume increase with discharge energy. The volumetric wear ratio linearly rise with energy index. The proportion of cathode as well as anode wear reduce with decreasing discharge duration. E. Aligiri et al.[10] used a novel tool wear compensation process to estimate material removal volume in real time. The single electrical discharge electro-thermal model is combined with online monitoring of EDM discharge gap. The electro-thermal model is used to estimate a unit material removal volume while the online monitoring process is employed to count the quantity of discharge pulse moreover to discriminate µEDM pulse. T. Koyano et al.[11] studied the use of electrostatic induction feeding method in µEDM to obtain good MRR and accuracy. The machining speed shows higher as well as lowerthe destroyed machined surface compared with the conventional relaxation pulse generator. Shuliang Dong et al.[12] discussed improvement of surface morphology of beryllium alloy with multi-diameter electrode in addition to various dielectrics in µEDM. The machining time is more for production similar deep holes with kerosene than deionized water. The liberated carbon from kerosene during discharge placed on the base of the blind holes leads to the MRR. The machining time also small for reaming hole in kerosene because of good flushing.

III. Electrode Wear

The EW is the ratio of the volume of material removed from electrode to volume of material removed from work-piece. Mu-Tian Yan et al. [13] presented the front and corner wear of tool improved quickly in µEDM drilling and milling. They also concluded EW compensation method shorten machining time. D.T. Pham et al.[14] analysed the effect of micro EW in EDM drilling of aluminium, brass and steel specimen with micro rod and micro tube electrodes. The rod electrode showed more deviation in the wear ratio through the depth of the hole. During machining of brass and aluminium, good flushing accepted to avoid side sparking of the electrode. The steel is the most preferable material among all the materials due to negligible effect by the flushing conditions. Pil Joo Cho et al.[15] observed the micro-hole produced in µEDM. They concluded that higher value of EW and machining time due to discharge inductance. In addition the machining time raise with improvement of charging resistance. Y.C. Lin et al.[16] developed model for µEDM of tool steel They summarized minor value of peak current reduces the EW and overcut, and improve the MRR. Eckart Uhlmann et al.[17] observed effect of grain size of the boron doped CVD diamond coating on the wear behavior in micro sinking EDM. The nano crystalline coatings reveals smaller discharge craters comparison with other microcrystalline diamond coatings, and microcrystalline coating. B. B. Pradhan et al.[18] optimized process parameters of µEDM of Ti-6Al-4V super alloy In addition, a developed mathematical is used to set up the correlation between different process parameters and µEDM performance criteria. The machining rate is linearly improved with peak current whereas it shows nonlinear relation with pulse on time. The higher value of TWR is observed due to high current leads to more discharge energy density. The TWR also shows linear relation with pulse on time because of high machining time. The more value of pulse current leads to improvement of over cut. The taper of the micro-hole is reduces with the raise in peak current. The higher value of pulse on time also improves the white layer is thickness. In addition, the surfaces roughness of the micro holes increase with both pulse current and pulse on time. M-G. Her et al. [19] observed micro-hole EDM of copper plate and tungsten carbide and copper-electrode tool. They noticed both EW and hole growth are lesser for straight polarity while both EW and machining speed are more for reverse polarity machining. In addition, straight polarity shows superior surface roughness than reverse polarity machining. The MRR is high for negative polarity machining . Mu-Tian Yan et al.[20] investigated multi cut and, front as well as corner wear of tool electrode for 3D µEDM using. They concluded corner wear ratio increases with machining length. In addition multi-cut process planning and electrode wear compensation processes increase µEDM accuracy in addition to decrease machining time of µEDM. The corner wear ratio improves with rise of the machining length.

Yao-Yang Tsai et al.[21] described electrode wear of different materials in µEDM based on the thermal properties. They observed, the material with high boiling point, melting point and thermal shows lower volumetric wear ratio. In addition, the corner wear is more due to low thermal conductivity of electrode. K.P. Rajurkar et al.[22] developed a combined CAD/CAM method with µEDM for the analysis of tool wear using uniform wear method during the machining of 3D micro cavity. The cylindrical electrode shows smaller electrode wear ratio than square electrode. This machining process reduces the cost and preparing time for the complicate electrodes results high production rate. G. D'Urso et al.[23] revealed effect tool wear ratio of electrodes and work-piece materials using µEDM technology. For the lower as well as higher value of peak current/voltage, the tungsten carbide electrode shows the low tool wear ratio. Whereas the brass electrode shows the highest level of tool wear ratio for this same condition. The magnesium specimen represent higher value of diamaterial over cut than specimen. Only copper electrode provides constant diamaterial over cut. In addition. the brass and copper electrode at more value of the peak current/voltage leads poor surface quality because of the additional parameter arrangement assumed for the machining. Jun Wang et al.[24] studied how the tool wear decrease with attachment of diode in the discharge circuit to obstruct the reverse current flow. A pulse counting technique used to calculate the number of effective pulses. They found that the reverse current is advantage for the MRR as well as the volumetric relative wear. This situation also improves surface quality because of high influence pulse frequency results high crater density. The crater structure reveals that reverse current flow facilitates smoothen the craters edge. Venugopal .T.R et al.[25] fabricated a µEDM with piezo actuated tool feed system for the measurement of tool wear as well as machining depth.

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They concluded blind hole depth measurement method is validate with other hole depth measurement system. This fabricated µEDM used for analysis of different process parameters.

IV. Surface Morphology Analysis

The surface morphology of µEDMed specimen analysis is discussed with both process parameter and machining performance. M. Murali et al.[26] revealed the application of foil shape electrode to explain spark erosion technique for micro machining of straight line features. The surface obtained by gravity assisted µEDM is even compared to Fast EDM. Because of good debris elimination, the material erosion manner is better in gravity assisted µ EDM than Fast EDM. Gunawan Setia Prihandana et al.[27] during powder mixed dielectric (PMD) µ-EDM process, provide good surface morphology and more rapidly machining time. The nano graphite fine particles in dielectric fluid with ultrasonic vibration increases the frequency of discharge leads to shorten the total machining time and increase the accuracy of the PMD µEDM process. Biing Hwa Yan et al.[28] observed the effect of different roughness as well as size on the bending fracture microWC-shafts produced in µEDM. The same size samples in machining noted that mean bending fracture strength is non linear relation with surface roughness in addition to the bending fracture possibility. Whereas for same roughness samples the length or axial surface area is inversely proportional to the mean bending fracture strength, moreover it is directly proportional to the bending fracture probability. The samples with small diameters decrease the surface roughness and the bending fracture probability. Sheng Ho Huang et al.[29] showed µEDM of identical samples the mean fracture strength reduces with the more value of surface roughness , and the possibility of fracture of the samples also increases. M.P. Jahanet al.[30] established a comparative study of various electrodes namely W, CuW and AgW in die-sinking µEDMed surface. AgW is the most suitable electrode among all because it provides smooth and polished surfaces. In addition, it offers good electrical and thermal properties compared to other EDM electrodes .

V. Microstructure of µEDMed work-piece

S. H. Yeo and G. G. Yap et al.[31] summarized the use of micro EDM to produce the photo mask for the application of micro electromechanical system. The use of µEDM also reduce capital and operating cost. K.P. Maity et al[32] investigated micro machining of copper using tungsten electrode. From this experiment, it was noticed that low value of capacitance improves holes quality with lower error of circularity as well as recast layer thickness. The capacitance also shorten machining time, while RPM shows least affect on machine time. Similarly the capacitance exhibits the maximum effect on the recast layer thickness but feed have the slightest effect on the recast layer thickness. Muhammad Imran et al.[33] studied drilling of micro-holes in Inconel 718 alloy. It improves minor thickness a with feed rate and cutting speed. G. Paul et al.[34] showed µEDM of aluminide alloy work piece with steel electrode. The air medium µEDM reveals low overcut because of higher open voltage and capacitance. S. Kanmani Subbu et al.[35] revealed the plasma observed in dry µEDM is ideal. Further improvement of discharge energy leads to enlarge the crater size as well depth. A Cheng Wang et al [36] revealed the use of µEDM for the manufacturing of micro slit die. Both average slit width along with depth are important for the accuracy of micro slit die. From their experiment it was shown that both average slit width and average slit depth are nonlinear relation with dielectric flushing pressure due to unstable discharge effect. Further the average slit depth first increases with open voltage because of better discharge and then it decrease due to minor gap between the copper foil and micro fin result difficult to remove the debris. The various areas of µEDM has been depicted in Figure 1 which are material removal rate, electrode wear, surface quality and microstructure of µEDMed work-piece . This figure narrates the optimised state of both process variable and machining performance of µEDM.

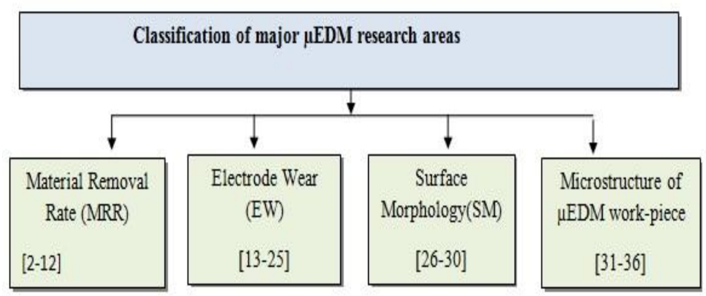

Figure 1. Classification of major µEDM research areas (corresponding section numbers are in brackets)

VI. Conclusion

In this paper, an overview of both optimization of the process parameters such as gap voltage, peak current and pulse duration in addition to machining performances namely MRR, EW, surface quality and microstructure of µEDMed specimen are being considered. This paper would support the researcher to consider the optimization of process parameter and machining performance of µEDM. For that reason µEDM processes will continue for competition as a micro-manufacturing technology.

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