Study the effect of process parameters on Electric Discharge Machining: Literature Review

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Abstract: Electrical discharge machining (EDM) is one of the earliest non-conventional method of manufacturing processes. This process based on thermoelectric energy between work piece and electrode and they must have electrical conductivity to generate the spark. A spark generated between work piece and electrode, and removes the material from work piece through melting and vaporizing. EDM produced various types of products such as dies and moulds. EDM is used to manufacture the parts of aerospace, automotive industry and surgical components. The effect of the machining parameters on surface roughness, metal removal rate and tool wear rate are studied.

Keywords: Lean manufacturing, Value Stream Mapping, Takt time, Kanban, Pareto chart

1. INTRODUCTION
In industry, production activity is carried out to manufacture the products. The process of manufacturing the product of hard materials is difficult. The electric discharge machining process is used to manufacture the product of hard materials. The influence of various input parameters on surface roughness (SR), metal removal rate (MRR) and tool wear rate (TWR) are studied and the activities involves to obtain the results.

2. LITERATURE REVIEW
Kolli and Kumar (2014) worked on titanium alloy (Ti–6Al–4V) with copper as the tool material and he want to check the effect of B4C powder mixed into dielectric fluid on EDM.

Fig. 1 Material removal rate v/s B4C powder concentration

Fig. 2 Surface roughness v/s B4C powder concentration

Fig. 3 Tool wear rate v/s B4C powder concentration
They investigated that mixing of B4C powder into the dielectric fluid has significantly improves the material removal rate by improving electric discharge density and spark gap. B4C powder in dielectric fluid improves surface roughness. Optimum material removal rate and surface roughness is achieved when the concentration is at 15gm/lit. High concentration levels of B4C powder resulted in good surface finish, less craters and cracks. Mhatre et. al. (2014) used a grey relation optimization technique for EDM characteristics of titanium alloy with two different electrode material such as copper and aluminium. From grey relational analysis (GRA), the optimum values found are duty cycle (8%), pulse current (18A), pulse on time (200µs) and voltage (40V).

Scanning electron microscopy (SEM) photographs are used for analysis. Among the various parameters, pulse current is the most significant factor affecting MRR, dimensional accuracy and surface integrity of drilled hole. For better surface finish, high MRR and less electrode wear, Cu is comparatively better electrode material than Al.

Kumar et. al. (2015) investigated mechanical properties and MRR, TWR in EDM process of Al2618 alloy reinforced with Si3N4, AlN and ZrB2 composites with copper as a tool material. EDM machining of Al2618 composites has a smaller amount of MRR, TWR and Depth with the influence of composites.

![Fig. 4 SEM photograph of Ti-6AL-4V alloy (sample 1)](image1)

![Fig. 5 SEM photograph of Ti-6AL-4V alloy (sample 2)](image2)

![Fig. 6 Hardness vs amount of reinforcement](image3)
Fig. 7 Ultimate tensile strength vs Amount of reinforcement

Fig. 8 Ultimate compressive strength vs amount of reinforcement

Tensile strength and compressive strength increases in Al2618 composites which increases the wt% of reinforcements and are evenly distributed and having continuous locations and having the high strength. The Micro Vicker's Hardness test shows that the hardness increases with respect to increasing the wt% of Al2618 alloy due to the decreasing of plastic deformation.

Bhuyan et. al. (2015) used TOPSIS method to optimize the process parameters of Al–24%SiC metal matrix composite during EDM process taking copper as the tool material. Response surface methodology (RSM) technique used to build the mathematical relation of the response parameters are defined in terms of process parameter. The mathematical model is quadratic in nature involving linear and quadratic interactions of process variables for closeness coefficient. It is observed that multi-response TOPSIS method is suitable for optimizing the machining characteristics during any machining process.

Talla et. al. (2015) worked on modeling and multi-objective optimization of powder mixed EDM process of aluminum/alumina metal matrix composite using copper as a tool material. Non-linear regression relationships obtained for different responses namely MRR and Ra (average roughness) are developed. The proposed PMEDM process, using aluminum suspended kerosene dielectric for the machining of resulted in better MRR when compared to conventional EDM process. It is observed that a significant decrease in Ra. PCA (principal component analysis) technique has been used to determine the weightages for responses while GRA (grey relational analysis) has been used to combine the multiple objectives into single. This optimization helps to determine the suitable machining parameters for high MRR and low Ra. The recommended process parameter setting for the proposed process has been found to be Cp= 4 g/l, Ip= 3 A, Ton= 150 ms and Tau= 85%.

Fig. 9 Perturbation plot illustrating the influence of EDM parameters on the MRR

Fig. 10 Perturbation plot illustrating the influence of EDM parameters on the TWR
Barenji et al. (2016) worked on prediction and modeling of the material removal rate and tool wear ratio of AISI D6 tool steel on EDM with copper electrode. The ANOVA analysis revealed that the models can be successfully applied for prediction of MMR and TWR. Moreover, with increasing the pulse on time during EDM, the MMR increased while the TWR decreased. In addition, higher values of pulse current cause to higher amounts of both MMR and TWR. Similarly, higher amounts of input voltage lead to lower values of both MMR and TWR. Furthermore, the highest and lowest values of 42.34 mm3/min and 1.63% were predicted by developed models, respectively for the MMR and TWR during EDM of AISI D6 tool steels. The optimized values of pulse on time (A), pulse current (B) and input voltage (C) to get relatively maximum and minimum amounts of MMR and TWR were 40 µs, 14 A and 150 V.

Li et al. (2016) investigated surface characteristics of titanium alloy by EDM with Cu–SiC composite electrode. As compared with Cu electrode, Cu–SiC electrode have shown better results. The surfaces processed have bigger radius of spark marks and fewer number of cracks.

When machining with Cu–SiC electrode, new phases of TiC and TiSi2 were created which consists of hardened layer (700-750HV). Rengasamy et al. (2016) analyzed the mechanical properties and optimization of EDM process parameters of Al 4032 alloy reinforced with Zrb2 and Tib2 in-situ composites. Most influencing process parameter in obtaining minimum MRR, TWR, and depth are obtained value about 0.190 (g/min), 0.005 (g/min) and 2.155 (g/min) from the input parameter value of about 8 Wt.% composites, Ton, Toff, Current of about 7.0 (µs), 7 (µs), 26 (Amps) respectively. The ANOVA method is used to calculate the percentage of contribution of each process parameter in influencing the material removal rate is composites (81.53%) followed by Pulse ON (8.72%) and Pulse OFF (4.26%).

![Fig. 11 SEM of EDMed surfaces processed with Cu–SiC electrode.](image1)

![Fig. 12 SEM of EDMed surfaces processed with Cu electrode.](image2)

![Fig. 13 Variation of current (amps) with MRR (g/min).](image3)

![Fig. 14 Variation of current (amps) with TWR (g/min).](image4)
Fig. 15 Variation of current (amps) with Depth (g/min).

Fig. 16 Variation of pulse on ($\mu$s) with MRR (g/min).

Fig. 17 Variation of pulse on ($\mu$s) with TWR (g/min).

Fig. 18 Variation of pulse on ($\mu$s) with Depth (g/min).

Fig. 19 Variation of pulse OFF ($\mu$s) with MRR (g/min).

Fig. 20 Variation of pulse OFF ($\mu$s) with TWR (g/min).

Fig. 21 Variation of pulse OFF ($\mu$s) with Depth (g/min).
Tool wear rate is influenced by process parameter in percentage of contribution is composites of (80.46%) and next is Pulse ON (8.59%) and Pulse OFF (2.34%).

The depth of cut is influenced by the process parameter in percentage of contribution is composites of about (94.95%), Pulse ON (3.76%) and Pulse OFF (0.50%). The variation of current (amps), Pulse ON, Pulse OFF of the Al 4032 composite alloy is measured as a function of MRR (g/min), TWR (g/min) and DEPTH (g/min), it proves that, the increase in reinforcement particles such as Zrb2 and Tib2 with matrix alloy enhances the hardness property and strength where the MRR, TWR and depth are minimum and affecting removal rate.

Roy et. al. (2016) checked the machinability of Al/10%SiC/2.5%Tib2 MMC with Powder-Mixed Electrical Discharge Machining (PMEDM) using copper electrode. The factors such as Ip, Ton and concentration have significant contribution in MRR, TWR and Ra model. High MRR of 171.41 mg/min is obtained at a high peak current of 8 A, high pulse on-time of 70 µs, and low concentration of 0 g/l Al powder (pure kerosene). Low TWR of 0.3 mg/l is obtained at low peak current (2 A) and low pulse on-time (30 µs) and high concentration of aluminium powder (4 g/l) mixed kerosene.
To produce low Ra values, a low peak current of 2 A, low pulse on-time of 30 µs, and higher concentration of powder of 4 g/l should be selected.

Kumar et. al. (2017) experimented on effect of cryogenically treated copper-tungsten electrode on tool wear rate during EDM of Ti-5Al-2.5Sn alloy. It is observed that Deep cryogenic treatment (DCT) copper-tungsten electrode contributes in low TWR. Higher S/N ratio is shown for DCT electrode which indicates the reduction in TWR as compared to without cryogenic treatment (WCT). It is well known that, cryogenic treatment has a history to improve mechanical, electrical and thermal properties of materials.

Due to generation of high temperature, surface and metallurgical properties of tool surface is also affected. From the micrographs, it can be seen that the process produces irregular surface texture and also defects such as globules of debris, pin-holes, and spherical particles with craters of varying sizes, micro-cracks, pockmarks, spherical nodules, recast layer, pull out materials on tool surface. The peak current was observed to be the most significant factor, which highly affected the surface properties of electrode surface. The SEM and XRD images are in agreement with the results reported. Without cryogenic treatment (WCT) and Deep cryogenic treatment (DCT) of Cu-W electrode were used to study their effects on TWR. Improvement of 15.86% was observed in case of DCT electrode than WCT electrode caused by refinement of grain particles. Peak current was observed to be most significant process parameter that badly affected the TWR.

Rahul et. al. (2017) emphasized on surface integrity and metallurgical characteristics of Inconel 825 on
EDM using cryogenically treated copper electrode. Cryogenic treatment of tool has reduced residual stress and crystal imperfections; thus ensuring improved tool life and improved tool shape retention capability and also reduced tool wear.

In comparison with Non Treated tool, Cryogenically Treated Tool has many advantages like: reduced (\sim 12\%) crystallite size and increased (\sim 28\%) dislocation density; reduced crack density; carbon enrichment on the work surface has been found relatively less; higher hardness values etc.

Torres et. al. (2017) worked on EDM machinability and surface roughness analysis of TiB2 using copper electrodes. In the case of the MRR variable, current intensity and duty cycle turned out to be the most influential parameters, to such an extent that an increase of both parameters led to higher MRR values.
EDX and SEM spectrum studied for analysis of minimum and maximum for Ra. Also, the maximum MRR was 3.0400 mm³/min (I = 6 A, η = 0.6), while the minimum value was 0.1607 mm³/min (I = 2 A, η = 0.4). Shabgard and Khosrozadeh (2017) carried out the investigation of carbon nanotube added dielectric on the surface characteristics and machining performance of Ti–6Al–4V alloy in EDM process. Addition of multi wall carbon nanotubes (MWCNTs) have enhanced results in machining stability because of decrease of inappropriate sparks especially during low energy pulses and long pulse on times.

Fig. 31 Microscopic view of the machined surface by (a) EDM and (b) PMEDM process (12 A pulse current and 100 μs pulse duration at 100x magnification).

Fig. 32 SEM micrographs of the machined surface by (a) EDM and (b) PMEDM process (12 A pulse current and 100 μs pulse duration).

Fig. 33 SEM micrographs of the machined surface by (a) EDM and (b) PMEDM process (48 A pulse current and 100 μs pulse duration).
Lower surface roughness is provided with Carbon nanotubes (CNT) added dielectric as compared with conventional dielectric in stable machining, but in unstable conditions CNTs improve sparking stability, as a result surface roughness increases by the enhancement of material removal rate. Addition of CNT particles into dielectric decreases the length and the size of surface micro cracks.

Bhuyan et. al. (2017) predicted the surface roughness during EDM of Al-SiCp MMC using RSM and Fuzzy logic approaches. The full factorial design of Central Composite Design (CCD) counted in the quadratic model. Non-linear regression relationships obtained for different surface roughness (SR) responses namely Ra, Rq and Rz are developed. Comparison is done for SR of substrate material during EDM process by RSM which is an analytical method and fuzzy logic which is a soft computing technique. Both methodology gave a close correlation between the predicted results and the experimental results but fuzzy logic technique give less percentage of error in compare to RSM. Finally, the significance of each process parameter with the selected response is analyzed by using ANOVA.

Mohanty et. al. (2017) carried an experimental investigation of machining characteristics for Al-SiC12% composite in EDM with copper tool. The full factorial design of Central Composite Design (CCD) counted in the quadratic model with two level factors (low, -1 and high, +1). Non-linear regression relationships obtained for different responses namely MRR, TWR and SR are developed. It is evident from the ANOVA results that as the current increases, MRR increases, TWR increase with the increase in peak current and Surface finish varies directly with current.

Sahu et. al. (2018) done the experimental investigation of Inconel 718 Super Alloys on EDM. It has been observed that the pulse on time is directly proportional of MRR, surface crack density and white layer thickness.
SEM and XRD analysis has revealed no significant phase transformation has occurred with Inconel 718 after EDM process. Formation of Nickel-Nyobium has been found on the EDMed specimen surface. Significant grain refinement has been incurred within the work material during EDM process followed by increase in strain and dislocation density.

Baroi et. al. (2018) worked on Electric Discharge Machining of Titanium Grade 2 Alloy and its Parametric Study. Optimum MRR of 0.0053367 g/min is observed at 15 A current and 106 μs pulse on time, optimum TWR of 0.0000067 g/min is achieved at 6 A current and 1010 μs pulse on time, and optimum SR of 2.960 μm is achieved at 6 A current and 25 μs pulse on time.
SR increases with increase in both current and pulse on time due to the formation of deep craters with an increase in energy.

Kumar et. al. (2018) analyzed MRR and SR in machining of titanium alloy using EDM process with copper electrode. Highest MRR was noted at combination of highest discharge current (18A), moderate pulse in time (150 μs) and lowest voltage (40V) supply. MRR increases with discharge current whereas voltage and pulse on time does not affect significantly. Ra is found to be largest at higher values of Ip, T on and Vg whereas it is lowest at lowest magnitude of input variables.

Gowthaman et. al. (2018) studied about Monel-Super Alloy using EDM process with copper as a tool material. Non-linear regression relationships obtained using MINITAB 17 software for different responses namely MRR and Ra are developed. Through GRA, it is identified that the Ip has a greater influence with the contribution of 82%, followed by T on with 12% and T off with nearly 4%. The optimized machining conditions to get the acceptable level of output responses are: Pulse on Time of 307 μs, Pulse off time of 2867μs, Discharge current of 15 A and Gap voltage of 80 Volts. Regression analysis is used for validation of the experimental data, and the error percentage is found to be less than 3%.

Kar et. al. (2018) investigated the influence of Process Parameters in Electric Discharge Machining of Aluminum – Red Mud Metal Matrix Composite using brass rod as tool material. Non-linear regression relationships obtained using MINITAB software for different responses namely MRR, EWR and ROC (radial over cut) are developed. It has been found that the peak current is found to have significant influence on the responses when compared with the other inputs, namely pulse on time and gap voltage. The results of ANOVA and the values of coefficients of correlation suggested a good statistical validity for the non-linear regression models of the responses.

Conclusion

From the published work, it is clear that most of the research used pulse on time, pulse off time and current as input parameters for studying the surface roughness, metal removal rate and tool wear rate. Copper tool materials used by most of the researchers in their work. SEM and XRD are used by the researchers.

References


