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Recent Advancement In Electric Discharge Machining, A Review

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ABSTRACT: *Electric discharge machining is non conventional machining process used for machining of hard materials which cannot machined by conventional machining process. Electric discharge machining is an electro sparking method of metal working involving an electric erosion effect. A pulse discharge occurs in a small gap between the work piece and the electrode and removes the unwanted material from the parent metal through melting and vaporizing*

Keyword: *Cryogenic, EDM, surface finish, Wear*

I. INTRODUCTION

Electric discharge machining is a non conventional machining process and has found its wide application in making moulds, dies, and in aerospace products and in surgical equipments[1]. The process is based on removing material from a part by means of a series of repeated electrical discharges between tool called the electrode and the work piece in the presence of a dielectric fluid [2]. The electrode is moved toward the work piece until the gap is small enough so that the impressed voltage is great enough to ionize the dielectric [3]. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical discharges from tool and work piece [4]. EDM machining does not involves direct contact of tool and work piece [1].Material of any hardness can be cut by EDM only condition it should be electrically conductive [5]. In this review paper, various trends in electric discharge machining has been considered involving powder mixed electrolyte used for EDM, incorporating tool vibration, green EDM (dry EDM), treatment of electrode used for EDM, and validating EDM performance using modeling techniques.

II. POWDER MIXED ELECTROLYTES.

In this process the fine abrasive particles are mixed with the electrolyte. Powder mixed EDM process is called hybrid machining process and called as PHEDM [6]. Electrically conductive powder reduces the insulating strength of the dielectric fluid and increases the spark gap between the tool and the work piece. EDM process becomes more stable and improves machining efficiency, MRR and surface quality.However; most studies were conducted to evaluate the surface finish since the process can provide mirror surface finish which is a challenging issue in EDM. The characteristics of the powder such as the size, type and concentration influence the dielectric performance [7].

2.1 SURFACE FINISH

Ming and He [8] indicates that some conductive powder can lower the surface roughness and the tendency of cracks in middle finish and finish machining but the inorganic oxide additive does not have such effect. Wong et al. [9] compares the near mirror- finish phenomenon using graphite, silicon (Si), aluminum (Al), crushed glass, silicon carbide (SiC) and molybdenum sulphide with different grain size. Al powder has been reported to give mirror finish for SKH-51 work pieces, but not on SKH-54 work pieces. They suggested that it is important to have the correct combination of Powder and work piece materials. Fu-chen [10] investigates the effect of powder properties on SQ of SKD-11 work piece using Al, chromium (Cr), Copper (Cu), and SiC powders. The smallest particle (70–80 nm) generates best surface finish and Al powder produces the best surface finish.

2.2 MATERIAL REMOVAL RATE

Jeswani [11] revealed that the addition of about 4 g/l of Fine graphite powder in kerosene increases MRR by 60% and tool wear by 15%. Yan and Chen [12] describes the effect of dielectric mixed with electrically conductive powder such as Al powder on the gap distance, surface roughness, material removal rate, relative electrode wear ratio, and voltage. waveform. It is shown that the dielectric with suspended electrically conductive powder can enlarge the gap distance and can improve the energy dispersion, surface roughness, and material removal rate. Machining efficiency and surface roughness of rough PMEDM in rough machining was studied by Zhao et al.[12] using Al with 40 g/l and 10 mm granularity and they discovered that machining efficiency was improved from 2.06 to 3.4mm^3/min with an increase in rate of 70%. The Machining efficiency can be highly increased by selecting Proper discharge parameter (increasing peak current and Reducing pulse width with better surface finish in comparison with conventional EDM machining. Y.F. Tzeng, and Lee [13] indicated that the greatest MRR is produced by chromium and 70–80 nm of grain size. Kansal et al. [14] established optimum process conditions for PMEDM in the rough machining phase using the Taguchi method with Graphite powder and found out that addition of an appropriate amount of the graphite powder into the dielectric fluid caused discernible improvement in MRR and reduction in tool wear as well as in surface roughness. Pec [15] investigates that powder mixed electrolyte conditions promotes the reduction of surface roughness, crater diameter, crater depth and the white-layer thickness. it was confirmed that electrode area influence on the surface quality produced. This influence was mathematically described by several linear equations relating the surface roughness, the white-layer thickness, the crater depth and width to the electrode area as the independent variable. Moreover, it was found that the sensitivity of the surface quality measures to the electrode area is smaller when mixed-powder dielectric is used. Also, powder-mixed dielectric significantly reduces surface heterogeneity contributing to increase process robustness. So, it contributes to the performance of the EDM process particularly when large electrode areas are involved and when a high-quality surface is a requirement.

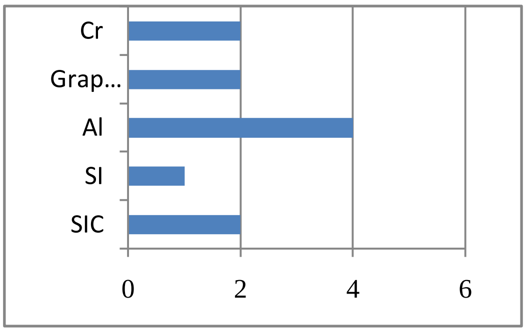

Fig. Various additives used in electrolyte based on collected papers

2.3 CONCLUSION

Use of powder in electrolyte provide mirror like surface finish and increase in material removal rate. Proper work piece and powder combination must be used for better results...

III. TOOL VIBRATION

Introduction of ultrasonic vibration to the electrode is one of the methods used to expand the application of EDM and to improve the machining performance on difficult to machine materials. The study of the effects on ultrasonic vibration of the electrode on EDM has been undertaken since mid 1980s. The higher efficiency gained by the Employment of ultrasonic vibration is mainly attributed to the better circulation of dielectric and debris removal from work piece [16]. Zhang et al. [17] proposed spark erosion with ultrasonic frequency using a DC power supply instead of the usual pulse power supply. The pulse discharge is produced by the relative motion between the tool and work piece simplifying the equipment and reducing its cost. They have indicated that it is easy to produce a combined technology which benefits from the virtues of ultrasonic machining and EDM.

3.1 VIBRATION, ROTARY AND VIBRO-ROTARY

Ghoreishi and Atkinson [18] compared the effects of high and low frequency forced axial vibration of the electrode, rotation of the electrode and combinations of the methods (vibro-rotary) in respect of MRR, tool wear ratio (TWR) and surface quality (SQ) in EDM die sinking and found that vibro-rotary increases MRR by up to 35% compared with vibration EDM and by up to 100% compared with rotary EDM in semi finishing.

3.2 CONCLUSION

Ultrasonic vibration makes the equipment simple and increases the material ejection from work piece.

IV. DRY MACHINING

In dry EDM, tool electrode is formed to be thin walled pipe. High-pressure gas or air is supplied through the pipe. The role of the gas is to remove the debris from the gap and to cool the inter electrode gap. The technique was developed to decrease the pollution caused by the use of liquid dielectric which leads to production of vapor during machining and the cost to manage the waste. Yu et al. [19] investigated the capability of the technique in machining cemented carbide material and compared the machining characteristics between oil EDM milling and oil die sinking EDM. They found that for machining the same shape, oil die sinking EDM shows shorter machining time. But because oil die sinking requires time for producing Electrodes, dry EDM should be more useful in actual production. The information given in this paper is interesting and they are reproduced here for better clarity.

Figs. 1 and 2 show the work removal rate and electrode Wear ratio in groove machining. According to the results, work removal rate of dry EDM milling is about six times larger than that of oil EDM milling, and electrode wear ratio one-third lower. In Fig. 3, it is shown that the EDM method with the shortest machining time was oil die sinking EDM, dry EDM milling was second, and oil EDM milling third. The lowest electrode wear ratio machining was dry EDM milling (see Fig. 4).

4.1 CONCLUSION

Dry EDM is eco friendly machining. Pollution is reduced by use of gas instead of oil based dielectric. Work removal rate also get enhanced by dry EDM.

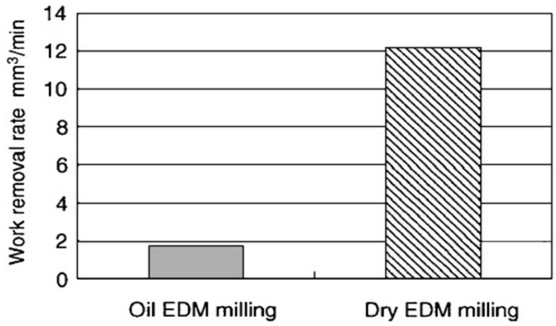

Fig 1 Work removal rate [19].

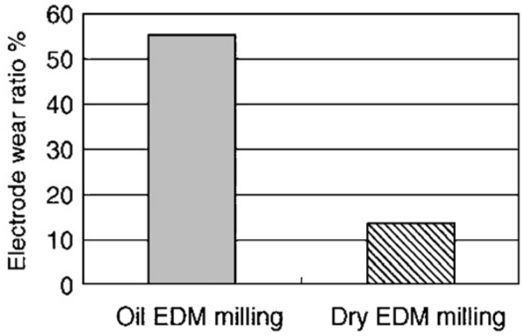

Fig. 2. Electrode wear [19].

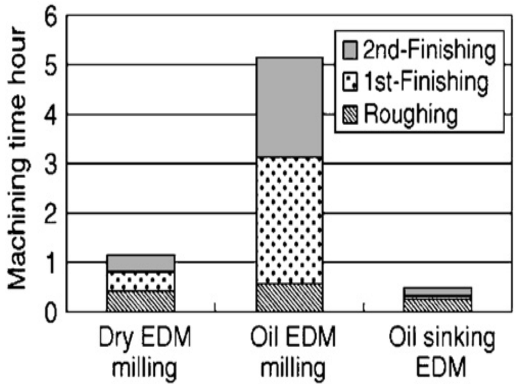

Fig 3 Machining time [19].

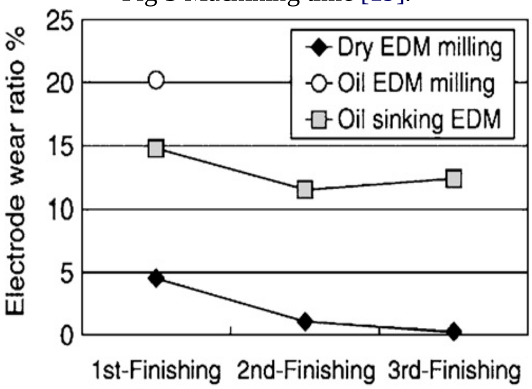

Fig. 4. Electrode wear ratio [19].

V. CRYOGENIC TREATMENT OF TOOL

The word cryogenic comes from the Greek word "kryos" which means cold. Cryogenic is the science of study of material at low temperature at which the properties of materials significantly change. Cryogenics processing is the treatment of the materials at very low temperature around 77K. This technique has been proven to be efficient in improving the physical and mechanical properties of the materials such as metals, plastics and composites. It improves the wear, abrasion, erosion and corrosion resistivity, durability and stabilizes the strength characteristics of various materials. Darwin [20] investigated that deep cryogenic treatment (DCT) is a one-time permanent process, carried out on steel components in such a way that the material is slowly cooled down to the cryogenic temperature, after which it is held at that temperature for a specified period of time and is heated back to room temperature at a slow rate followed by low temperature tempering. The DCT has a lot of benefits. It not only gives dimensional stability to the material, but also improves wear resistance, strength and hardness of the materials. Kalia [21 showed that cryogenic refines and stabilizes the crystal lattic e structure and distribute carbon particles throughout the material resulting in a stronger and hence more durable material.

5.1 TOOL WEAR

Abdulkarim [22] investigated the effect of cryogenic cooling on electrode wear and surface roughness of the work piece used in EDM process. By using the cryogenic cooling the electrode wear ratio reduced up to 27% and there was 8% improvement in the surface roughness. MRR can be increased with decrease in electrode wear by controlling the machine parameters. Copper is the main electrode in the EDM process because it has low electrical resistance and which help to transfer effectively energy to the work piece. The cooling effect of liquid nitrogen improves the electrical and thermal conductivity of copper and this effect in efficient heat transfer from the Cu electrode resulting in reducing the electrode wear. Singh [23] proved that cryogenic treatment improves the tool wear rate by 58.77% & reduces the surface roughness by 8%. For cryogenic Ti work piece minimum value (0.00943443 gm/min) of tool wear rate was achieved with cryogenic Ti as tool and value of current was 2 ampere. for plain Ti work piece minimum value of TWR (0.010418803 gm/min) was achieved with plain as Ti as tool and value of the current was 2 ampere. M. Dhananchezian [24] examined the machining of stainless steel inherently generates high cutting temperature, which not only reduces tool life but also impairs the work piece surface quality. Conventional cooling methods are ineffective in controlling the high cutting temperature and rapid tool wear. In the present research work, the effect of liquid nitrogen as a coolant applied through holes made on the rake and flank surfaces of the PVD TiAlN coated tungsten carbide turning tool inserts of ISO CNMG 120412 MP–KC5010 on the turning of AISI 304 stainless steel is studied. The influence of cryogenic cooling on the cutting temperature, cutting force, surface roughness, and tool wear, has been compared with those of wet machining. It has been observed that in the cryogenic cooling method, the cutting temperature was reduced by 44–51%, the cutting force was decreased to a maximum of 16%, and the surface roughness was reduced by 22–34% over that of wet machining. Cryogenic cooling using liquid nitrogen reduced tool wear through the control of temperature-dependant wear mechanisms.

5.2 CONCLUSION

Tool wear is reduced to large extent by cryogenic treatment treatment done on electrode. Surface roughness produced also lowered by use of cryogenic treated electrodes

VI. EDM IN WATER

Water as dielectric is an alternative to hydrocarbon oil. The approach is taken to promote a better health and safe environment while working with EDM. This is because Hydrocarbon oil such as kerosene will decompose and release harmful vapour (CO and CH_4) [25]. Research over the last 25 years has involved the use of pure water and water with additives.

6.1 PURE WATER

The first paper about the usage of water as dielectric was Published by Jeswani [26] in 1981. He compared the Performances of kerosene and distilled water over the pulse energy range 72–288 mJ. Machining in distilled water resulted in a higher MRR and a lower wear ratio than in kerosene when a high pulse energy range was used. With distilled water, the machining accuracy was poor but the surface finish was better. Tariq Jilani and Pandey [27] investigated the performance of water as dielectric in EDM using distilled water, tap water and a mixture of 25% tap and 75% distilled water. The best machining rates have been achieved with the tap water and machining in water has the possibility of achieving zero electrode wear when using copper tools with negative polarities. Konig and Siebers [28] explained the influence of the working medium on the removal process. They indicated that working medium has a sustained influence on the removal process. The erosions process in water-based media consequently possesses higher thermal stability and much higher power input can be achieved especially under critical conditions, allowing much greater increase in the removal rate. A considerable difference between conventional oil based dielectrics and aqueous media in term of specific boiling energy of aqueous media is eight times higher than oil based dielectric and boiling phenomena occur at a lower temperature level. During investigating on white surface layer, Kruth et al. [29] found that the use of an oil dielectric increases the carbon content in the white layer and appears as iron carbides (Fe_3C) in columnar, dendritic structures while machining in water causes a decarbonization. While investigating the influence of kerosene and distilled water as dielectric on Ti–6A1–4V work pieces. Chen [30] found that carbide is formed on the work piece surface while using kerosene while oxide is formed on the work piece surface while using distilled water. The debris size of Ti–6Al–4V alloy in distilled water is greater than that in kerosene and compared with kerosene, the impulsive force of discharge in distilled water is smaller but more stable. Ekmekciet et al. [31] presented an experimental work to measure residual stresses and hardness depth in EDM surfaces. Stresses are found to be increasing rapidly with respect to depth, attaining to its maximum value around the yield strength and then fall rapidly to compressive residual stresses in the core of the material since the stresses within plastically deformed layers are equilibrated with elastic stresses. In 2005, Sharma [32] investigated the potential of electrically conductive chemical vapor deposited diamond as an electrode for micro-electrical discharge machining in oil and water. While doing a comparative study on the surface integrity of plastic mold steel, Ekmekci [33] found that the amount of retained austenite phase and the intensity of micro cracks have found to be much less in the white layer of the samples machined in de-ionized water.

A new application in EDM power supply was designed to develop small size EDM systems by Casanueva. [34]. The proposed control achieves an optimum and stable operation using tap water as dielectric fluid to prevent the generation of undesired impulses and keep the distance between the electrode and the work piece within the optimum stable range. Studies conducted by Kang and Kim [35] in order to investigate the effects of EDM process conditions on the crack susceptibility of a nickel-based super alloy revealed that depending on the dielectric fluid and the post-EDM process such as solution heat treatment, cracks exist in recast layer could propagate into substrate when a 20% strain tensile force was applied at room temperature. When kerosene as dielectric, it was observed that carburization and sharp crack propagation along the grain boundary occurred after the heat treatment. However, using deionized water as dielectric the specimen after heat treatment underwent oxidation and showed no crack propagation behavior.

6.2 WATER WITH ADDITIVES

Koenig and Joerres [36] reported that a highly concentrated aqueous glycerin solution has an advantage as compared to hydrocarbon dielectrics when working with long pulse durations and high pulse duty factors and discharge currents, i.e. in the roughing range with high open-circuit voltages and positive polarity tool electrode. Leao and Pashby [37] found that some researchers have studied the feasibility of adding organic compound such as ethylene glycol, polyethylene glycol 200, polyethylene glycol 400, polyethylene glycol 600, dextrose and sucrose to improve the performance of deionized water. The surface of titanium has been modified after EDM using dielectric of urea solution in water [38]. The nitrogen element decomposed from the dielectric that contained urea, migrated to the work piece forming a TiN hard layer which resulting in good wear resistance of the machined surface after EDM.

6.3 CONCLUSION

Water based EDM is more eco friendly as compared to conventional oil based dielectric. The material removal rate enhanced with use of water.

VII. MODELING

EDM process is influenced by many input factors. Various techniques viz. dimensional analysis, artificial neural network and thermal modeling are employed to predict the output of the process mainly the surface finish, tool wear and MRR.

7.1 DIMENSIONAL ANALYSIS

In 1979 Jeswani [39] used the dimensional analysis to predict the tool wear in EDM. The equation relates the volume of material eroded from the tool electrode to the energy of the pulse and density, thermal conductivity, specific heat and latent heat of vaporization of electrode material. Yahya and Manning [40] applied the method in analyzing MRR. The electrical and physical parameters related to the process are discharge pulse on time, gap voltage, sparking frequency, gap current and material Properties.

Results from the model show good agreement when compared to experimental finding. A semi empirical model of surface finish [41], MRR and tool wear [42] for various materials have been established by employing dimensional analysis. Using design of experiment method, the process parameter viz. peak current, pulse duration, electric polarity and material properties are identified. The final results show that the average error between the experiment and prediction was less than 10% for surface finish model and less than 20% for MRR. However, the relations between tool wear and discharge time under different electric polarity are seen to have inverse effect.

7.2 MATHEMATICAL MODEL

Dibitonto [43] presented a simple cathode erosion model for EDM. The Compton original energy balance for gas discharges is amended and the model uses the photoelectric effect as the dominant source of energy supplied to the cathode surface. Then, Patel [44] developed the anode erosion model which accepts power as boundary condition at anode interface and assumed to produce a Gaussian-distributed heat flux on the surface of anode material. The area upon which the flux is incident is assumed to grow with time. A model on variable mass and cylindrical plasma was introduced by Eubank [45]. It consists of three differential equation-one each from fluid dynamics, an energy balance and the radiation equation combined with plasma equations of state. Problems with the zero-time boundary conditions are overcome by an electron balance procedure. McGeough and Rasmussen [46] proposed a model for electro discharge texturing based on the effect of dielectric fluid and in particular the influence of change in the resistance in the dielectric during each voltage pulse. The theoretical predictions confirm the practical findings that the surface roughness in texturing is determined primarily by the peak current used and the length of the voltage ‘on time’. Coguz [47] investigated on surface profile of 2080 tool steel machined under varying machining parameters. It is found that surface roughness increases with increasing discharge current, pulse duration and dielectric flushing pressure. Surface profile information obtained is transferred to computer, digitized and then modeled in the form of Fourier series. Perez [48] presented a model for relative power dissipation by taking into account the different current emission mechanism and cathode space-charge characteristics valid for refractory and non-refractory materials. Tantra et al. [49] tested the validity of model proposed by Heuvelman for erosion strength of material to predict tool wear and their applicability to EDM process such as drilling of deep holes in turbine blades. The experimental results show the Heuvelman model does not show a direct correlation with the observation. Work proposed a combination of Taguchi method and Top[sis to solve the multi-response parameter optimization problem in green electrical discharge machining. An analytical structure was developed to perform multi-criteria decision making. The responses were ranked based on the scores obtained by the summarization of final global preference weights. Triangular fuzzy numbers were used to assign preference values to the output responses. The optimum factor level combinations were identified based on the closeness coefficient values. The optimal machining performance for the green EDM was obtained for 4.5 A peak current (level 2), 261 lm pulse duration (level 2), 40 mm dielectric level (level 1) and 0.5 kg/cm2 flushing pressure (level 2). From analysis of the closeness coefficients, it was identified that the peak current was the most influential parameter in multi-performance characteristics used in this study. The computational and experimental effort needed to optimize these parameters was rather small. It was illustrated that the method was efficient and effective for multi-attribute decision making problems in green manufacturing. B. Izquierdo [50] presents an original thermal model capable of simulating discharge super position and representing EDM processed surfaces. The main conclusions obtained from this study are: Single-discharge modeling has been expensively studied in literature in order to characterize the EDM process. In this work, it has been shown that superposition of multiple discharges must be considered, since the amount of material removed per discharge increases (as much as 50%) as the operation progresses. This effect is related both to the stochastic nature of the process (discharge type and location) and the development of temperature fields on irregular surfaces. An original numerical model for simulation of the EDM process has been presented. The model generates EDM processede surfaces by calculating temperature fields inside the work piece using a finite difference-based approach, and taking into account the effect of successive discharges

7.3 ARTIFICIAL NEURAL NETWORK (ANN)

An attempt of modeling EDM process through ANN was carried out by Gopal and Rajurkar [51]. With machining depth, tool radius, orbital radius, radial step, offset depth, pulse on-time, pulse off-time and discharge current as the input parameters 9-9-2 size back propagation neural network was developed, experiments have been performed to check the validity of the ANN model and it can be concluded that the ANN model provides faster and more accurate results. Tsai and Wang [52] have compared the ANN model on MRR. Six neural network models and neuro-fuzzy model for MRR have been established and analyzed. Results show that adaptive-network fuzzy interference system (ANFIS) is more accurate with an error 16.33%. In their further investigations, Tsai and Wang [53] have applied the same method to predict the surface finish. Results show that tangent sigmoid multi-layered perception (TANMLP), radial basis function network (RBFN),

Adaptive RBFN and ANFIS models have shown consistent results. Wang [54] combine the ANN and genetic algorithm to find an integrated solution to the problem of modeling and optimization of manufacturing processes. The error of the model is 5.6% for MRR and 4.98% for surface roughness. The modeling system established better knowledge about interaction between tool (graphite) and work piece (nickel alloy). An artificial feed forward neural network based on the Levenberg–Marquardt back propagation technique has been developed by Panda and Bhoi [50] to predict MRR. The model provides faster, more accurate results and performs well under the stochastic environment of actual machining conditions without understanding the complex physical phenomena exhibited in electro-discharge machining.

7.4 CONCLUSIONS

Various input parameters like current, pulse on, pulse off time; voltage has been taken for model formation to produce the proper combination for machining.

VIII. SUMMARY

The study reveals that a lot work has been done on estimation of tool wear and material removal rate in EDM. Researcher works on reduction of tool wear and enhancement of material removal rate by experimental investigation. use of powder mixed electrolyte, tool vibration, dry EDM use of gas instead of oil electrolyte, treatment on tool used for EDM, water based EDM and modeling techniques has been employed for increase of EDM efficiency .There is lot gap and no work has done on composite and ceramics materials. No CFD model for electrolyte flushing rate has been employed and there is lot work can be done on mathematical model of EDM.

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