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A REVIEW ON DRY EDM AND NEAR-DRY EDM PROCESSES

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ABSTRACT

Electrical discharge machining process is a thermo-electric process where material is removed by the succession of electrical discharges occurring between an electrode and workpiece. In conventional EDM process liquid dielectrics like kerosene or hydrocarbon based oil is used which results in toxic fume generation during machining, carbon deposition on the machined surface etc which leads to environmental hazards. In order to minimize the environmental hazards and drawbacks, conventional liquid dielectric EDM process has been modified by using gaseous dielectric and mixture of gas and liquid dielectrics known as Dry EDM and Near-Dry EDM respectively. Dry and Near-Dry EDM process causes better debris removal and flushing due to lesser viscosity of gas. Concern of environmental hazard and fire hazard is nil in this process and provides better accuracy of machined surface than in hydrocarbon based oil EDM. In this paper a literature review of works done in the field of Dry and Near-Dry EDM process is been studied and further improvements in the process parameters are been studied for its successful industrial implementation.

Keywords: *Electrical Discharge Machining, Dry EDM and Near- Dry EDM*

1. Introduction

Electrical discharge machining is a non-traditional manufacturing process based on removing material from a part by means of a series of recurring electrical discharges between a tool called electrode and the part mentioned before in the presence of a dielectric fluid [1]. Electrical discharge machining (EDM) is a highly developed technology which accounts for about 7% of all machine tool sales in the world [2].

Electrical discharge machining (EDM) process is analysed, the main cause of environmental concerns is related to the use of mineral oil based dielectric liquids. High temperature, chemical breakdown of these dielectric liquids associated to the machining process generate toxic fumes and sometimes even fire hazards[3].So researchers modified the EDM machining thus making it an environmental friendly by changing the dielectric to dry and near-dry EDM.Dry and near-dry electrical discharge machining EDM processes use gas and liquid-gas mixture, respectively, as a dielectric medium to substitute the liquid dielectrics in a conventional EDM. In dry EDM gas is supplied to the discharge gap through a pipe electrode in order to eject debris particles from the gap and cool the discharge spot and electrodes.

Dry EDM is characterized by small tool electrode wear, negligible damage generated on the machined surface, and significantly high material removal rate especially when oxygen gas is used due to oxidation of the workpiece [4]. Near-dry EDM exhibits the advantage of good machining stability and smooth surface finish at low discharge energy input. Near dry EDM also has the benefit to tailor the concentration of liquid and properties of dielectric medium to meet desired performance targets.

A dispenser for minimum quantity lubrication (MQL) is utilized to supply a minute amount of liquid droplets at a controlled rate to the gap between the workpiece and electrode in this method. Near dry EDM shows advantages over the dry EDM in higher material removal rate (MRR), sharper cutting edge, and less debris deposition [5].In this paper a review on the research works in the field of dry and near-dry EDM will be covered.

2. Literature Review

2.1 EDM

2.1.1 Gas as dielectric in EDM

2.1.1.1 Die-sinking EDM

Ramani and Cassidenti researchers of NASA attempted first in the case of dry EDM, they used argon and helium gas as a dielectric and resulted that the process has lower material removal rate (MRR) rather than oil EDM process [6].Kunieda described a new method of EDM which is supplied with oxygen gas into the discharge gap when water based dielectric is used. He found that the stock removal rate of the oxygen

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assisted EDM is greater than that of conventional EDM [7].

Kunieda et al. studied the advantages of dry EDM process such as high MRR using oxygen as dielectric due to the heat generation by the oxidation of the work piece, negligible tool wear, less heat affected zones and white layers are thin. They found that micro cracks are less and process reaction force is negligible. There is no corrosion of the machined material due to electrolysis using deionized water as dielectric[8].Govindan and Joshi studied the performance of dry EDM using slotted electrodes. Use of electrodes with peripheral slots provide more space for the flow of dielectric for effective debris disposal and consequently improve the MRR. They optimized the number of peripheral slots on the electrode and found out that use of slotted electrodes reduces the electrode wear rate and reduces the attachment of debris particles to the electrode [16].

Besliu et al. did dry EDM drilling on low thickness steel plates. Tubular copper electrode was used as tool and compressed air was used as the dielectric. They compared dry and wet drilling and found out that the surface quality and the electrode tool wear are more advantageous in the case of the dry electrical discharge process. They connected the rotating electrode tool device to circuit of the relaxation generator. They proposed the use of a proper ram electrical discharge machine for further researches [3].Govindan and Joshi analyzed the micro cracks on the machined surfaces in dry EDM machining using oxygen as the dielectric. They analyzed the micro cracks in terms of length, number and orientation of micro cracks formed on the machined surfaces. They found that average length and number density of micro cracks were lower in dry EDM than those in liquid dielectric EDM process [11].Villeneuve and Curodeau experimented a new dry die- sinking EDM polishing method using a mouldable polymer composite electrode as tool. Experimental investigation was performed on the dry die- sinking EDM process to assess the feasibility of finishing down to 0.2- 0.3μm Sa and polishing from 0.2- 0.3μm Sa down to finest achievable surface finish [14].Roth et al. presented a paper which deals with the measurement of the MRR in function of different tool electrode and workpiece material along with the breakdown behavior of the dry EDM process. They inferred that the workpiece material has a major influence on MRR compared to effect of tool electrode material from their experiments on cemented carbide and stainless steel.The used electrode materials are pure copper and cemented carbide multichannel electrode [15].

2.1.1.2 Wire EDM

Lee and young investigated dry wire EDM experiments of thin workpieces using air as the dielectric fluid. They found out that the material removal rate (MRR) in dry EDM was much lower than that in wet EDM, and the effects of various EDM parameters on MRR were comparatively investigated in the cases of dry and wet wire EDM processes. The thickness of workpiece and work-material were critical ones to influence on the MRR [12].

Kunieda and Furudate developed a new dry wire EDM method and from the experiments they found that the vibration of the wire electrode is minute due to the negligibly small process reaction force. They also found that gap distance is small and there is no corrosion of the workpiece. High accuracy in finish cutting can be obtained using dry wire EDM process, but the MRR in this process is low as compared to conventional WEDM process [13].

2.1.1.3 EDM milling

Kunieda et al. investigated the high speed EDM milling of 3D cavities using oxygen gas as the working fluid. Results showed that the electrode tool wear is remarkably small and high MRR is possible when oxygen gas is used as the dielectric due to the extremely high oxidation of steel work pieces. From the experimental results they found that machining accuracy was better when gas was sucked through the pipe electrode than jetted [9].Zhan et al. found out that DEDM is suitable for 3D milling of difficult to cut materials such as cemented carbides. His investigations were based on the fact that DEDM has characteristics of high work removal rate, low tool electrode wear ratio and he alsofound that dry EDM milling is most advantageous to three-dimensional milling of cemented carbide considering the total machining time and cost [17].

2.2 Ultrasonic vibration with gas as dielectric

Zhang et al. used ultrasonic to improve the efficiency of EDM in a gas medium. He applied ultrasonic actuation onto the workpiece, used thin walled electrode and used high pressure gas as dielectric. He came to the conclusion that MRR is increased with respect to the increase of the open voltage, the pulse duration, the amplitude of the ultrasonic actuation, discharge current and the decrease of the wall thickness of electrode pipe. Another result they got from the experiment is that UDEM in gas, the MRR is nearly twice than EDM in gas, but less than that of conventional EDM [18].

2.3 Optimization and modelling

Saha and Choudary had done experimental investigation and empirical modeling of DEDM machining process. They performed parametric analysis of process with tubular copper electrode tool, mild steel workpiece and compressed air as dielectric. They found that Current, duty factor, air pressure and spindle speed have significant effects on MRR and Ra. TWR was found to be very small and independent of input parameters [19].Temouri and Baseri used a predictive model based on back propagation neural network, which correlate the input and outputs of dry EDM process. They also optimized the process for the best solutions for higher MRR and lower surface roughness simultaneously [20].

Sivapirakasam et al. aims to develop a combination of taguchi and fuzzy TOPSIS method to solve multi response parameter optimization problems in green manufacturing. It helps to make model for the selection of process parameters in order to achieve green EDM [21].Grzegorz and jerzy presented results of simulation and mathematical modeling of material removal rate of EDM process with compressed air as dielectric. They found that using two channel electrode in DEDM machining results were slightly better than in case of pipe electrode. Better surface finish and geometry of machined cavity was achieved using two channel electrode. They also found out that MRR is significantly higher during DEDM process with compressed air than in case of this process in kerosene. But the surface quality is poorer than in case of kerosene [10].

2.4 Pulsating magnetic field

Joshi et al. experimented dry EDM in a pulsating magnetic field for improving process performance. A pulsating magnetic field is applied in the experiment which is tangential to the electric field; this will increase the movement of electrons and degree of ionization in the plasma. They came to the conclusion that this method improves the productivity by 130% and the tool wear was about zero when compared with the dry EDM process without magnetic field.

2.5. Near Dry EDM

Tao et al. investigated the dry and near dry electrical discharge milling to achieve high material removal rate and fine surface finish for roughing and finishing operations respectively. They found that lower pulse duration and lower discharge current are the key factors for improving the surface finish in near dry EDM. From the experiments they selectedoxygen gas and copper electrode for high MRR dry EDM and the nitrogen-water mixture and graphite electrode for fine surface finish near-dry EDM [22].Kao et al. studied the wire EDM cutting and EDM drilling under wet, dry and near dry conditions. He found that near dry EDM shows advantages over the dry EDM in high MRR, sharper cutting edge and less debris deposition. Compared to wet EDM, near dry EDM has higher MRR at lower discharge energy and generates a small gap distance [5].

Song et al. in his paper investigated electrical discharge drilling with water spray for suppressing electrolytic corrosion in WC-Co. The water spray is composed of tap water and compressed air. The machining characteristics such as corrosion prevention effects, machining rate and electrode wear were investigated according to water spray conditions such as water flow rate and air flow rate. They also found out that the use of water spray instead of tap water prevented electrolytic corrosion around the machined holes without deterioration in the machining speed [23]. Tao et al. investigates near-dry EDM milling as a finishing process to achieve a mirror-like surface finish. Kerosene mist with air, coupled with a copper infiltrated graphite electrodewas found to produce the best overall results innear-dry EDM finishing.EDM power generator was modified in this experiment to enable the reduction of surface roughness. Effects of dielectric fluid, electrode material andpulse energy on material removal rate and surface roughness are also studied in this experiment [24].

3. Scope Of Future Work

Abbas et al. in his paper studied the practices in Malaysian industries and found that an estimated amount of 4393 litres of dielectric will be disposed by an average EDM manufacturer in Malaysia [25].So considering same manufacturing discipline in the whole world the pollution rate is really high, so dry and near-dry EDM can be a substitute to this present scenario. Industrial implementation of dry and near-dry EDM can be done only through more researches which will help in the improvement of material removal rate, reduction of tool wear, micro cracks, recast layer thickness, selection of dielectrics etc. Evacuation of debris particles out from the working gap and the difficulty of machining holes deeper than twice the electrode radius are some drawbacks of dry EDM[10]. These drawbacks have to be eliminated for its successful industrial implementation.

In the case of near-dry EDM the best liquid-gas mixture has to be studied and its optimum mixing proportion also. Overall more parameter studies have to be carried out in the area of dry and near-dry EDM. Trial implementation of dry and near-dry EDM machining has to carried out in industries and the problems occurring should be rectified.

4. Conclusion

From the literatures it is clear that the growth of EDM in manufacturing industry has been at its peak and it affects the environment due to the disposal of dielectric waste. Therefore an environmental friendly machining alternative in the area of EDM is unavoidable and Dry EDM and Near- dry EDM is future scope in EDM. Further researches has to be carried out in this area and its industrial implementation has to be worked out.

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