A Review on optimization of Dry Electro Discharge Machining Process Parameters

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Abstract—Dry EDM is an environmental friendly machining process were liquid dielectric is replaced by gaseous dielectrics. There are presented performance characteristics of the process, using various gases and their mixtures as dielectric medium. The main aim is to study the effect of gap voltage, discharge current, pulse-on time, duty factor, air pressure and spindle speed on Material removal Rate (MRR), Surface Roughness (Ra) and Tool Wear Rate (TWR). Influence of gas pressure, flow rate and rotational speed of the electrode are also discussed resulting in finding optimal conditions for machining, depending on the optimization criteria.

Key words: Dry EDM, MRR, Ra, TWR

I. INTRODUCTION

Electric discharge machining (EDM) is one of the most popular non-traditional machining processes being used today. Use of mineral oil-based dielectric liquids is the major cause of environmental concerns associated with the EDM process. Dry EDM is an environment-friendly modification of the oil EDM process in which the liquid dielectric is replaced by a gaseous medium. Dielectric wastes generated during the oil EDM process are very toxic and cannot be recycled. Also, toxic fumes are generated during machining due to high temperature chemical breakdown of mineral oils. The use of oil as the dielectric fluid also makes it necessary to take extra precaution to prevent fire hazards. Replacing liquid dielectric by gases is an emerging field in the environment-friendly EDM technology. High velocity gas flowing through the tool electrode into the inter-electrode gap substitutes the liquid dielectric. The flow of high velocity gas into the gap facilitates removal of debris and prevents excessive heating of the tool and work piece at the discharge spots. Providing rotation or planetary motion to the tool has been found to be essential for maintaining the stability of the dry EDM process. Tubular tools are used and as the tool rotates, high velocity gas is supplied through it in to the discharge gap. Tool rotation during machining not only improves the process stability by reducing arcing between the electrodes but also facilitates in the flushing of debris. The first reference to dry EDM can be found in a 1985 NASA Technical report [1]. It was briefly reported that argon and helium gas were used as dielectric medium to drill holes using tubular copper electrode. Further details are however not available. Later in 1991, Kunieda et al. showed that introducing oxygen gas into the discharge gap improves the material removal rate (MRR) in a water-based dielectric medium. It was in 1997 that the feasibility of using air as the dielectric medium was first demonstrated by Kunieda et al. High velocity gas jet through a thin walled tubular electrode was used as dielectric. Further research in this field has brought out some of the essential features of the process. It is now known that some of the advantages of the dry EDM process are: low tool wear, lower discharge gap, lower residual stresses, smaller white layer and smaller heat affected zone. Also, several studies have been made to improve the performance of the process such as by using a piezoelectric gap control mechanism and by introducing ultrasonic vibrations to the work piece. Dry EDM has also been successfully implemented in wire EDM operations. Tao et al. have recently reported that oxygen gas and copper tool combination leads to a high MRR in dry EDM and nitrogen gas water mixture dielectric and graphite tool combination leads to high surface finish in near- dry EDM. However, the current literature in the field is insufficient.

II. WORKING PRINCIPLE OF DRY EDM

Dry Electric Discharge Machining (Dry EDM) is a modification of the oil EDM process in which the liquid dielectric is replaced by a gaseous dielectric. High velocity gas flowing through the tool electrode into the inter-electrode gap substitutes the liquid dielectric. The flow of high velocity gas into the gap facilitates removal of debris and prevents excessive heating of the tool and work piece at the discharge spots. Providing rotation or planetary motion to the tool has been found to be essential for maintaining the stability of the dry EDM process. The dry EDM process schematic is shown in Figure 1.

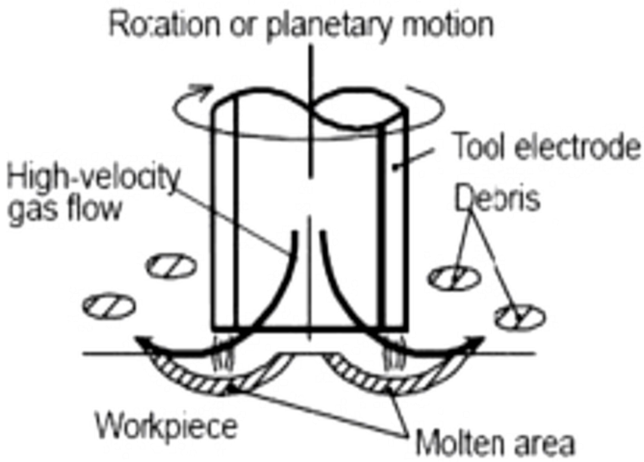

Fig. 1: Schematic of dry EDM process

Tubular tools are used and as the tool rotates, high velocity gas is supplied through it into the discharge gap. Gas in the gap plays the role of the dielectric medium required for electric discharge. Also, continuous flow of fresh gas into the gap forces debris particles away from the gap. Tool rotation during machining not only facilitates flushing but also improves the process stability by reducing arcing between the electrodes.

III. LITERATURE REVIEW

The first reference to dry EDM can be found in a 1985 NASA Technical report [1]. It is briefly reported that argon and helium gas were used as dielectric medium to drill holes using tubular copper electrode. Further details are not available.

Later in 1991, Kunieda et. al. [2] showed that introducing oxygen gas into the discharge gap improves MRR in a water based dielectric medium. Later in 1997, that the feasibility of using air as the dielectric medium was first demonstrated by Kunieda et al. [3]. High velocity gas jet through a thin walled tubular electrode was used to serve the purpose of a dielectric.

Yu et. al. [4] demonstrated the effectiveness of the dry EDM method in machining of cemented carbide. Dry EDM was used for groove milling and three- dimensional milling. Copper-tungsten tubes were used as tool electrodes and high velocity oxygen gas was used as the dielectric. Dry EDM performance was compared to oil die sinking EDM and oil EDM milling. It was found that dry EDM milling produces the smallest form deviation due to very low tool wear ratio. The machining speed in dry EDM is higher than for oil milling EDM but lower than oil die-sinking EDM. However, it was argued that the total time required for making multiple electrodes in die-sinking EDM puts it at a disadvantage to dry EDM milling. Fewer tool electrodes are required in dry EDM due to lower tool wear. The total machining time for dry EDM may then be lower than die-sinking EDM.

Q.H. Zhang, R. Du, J.H. Zhang, Q.B. Zhang et. al. [5] studies that an investigation of ultrasonic-assisted electrical discharge machining in gas. In the process of UEDM in gas, the tool electrode is a thin-walled pipe, the high-pressure gas medium is applied from inside, and the ultrasonic actuation is applied onto the work piece. In experiment, the work piece material is AISI 1045 steel and the electrode material is copper. The experiment results indicate that (a) the Material Removal Rate (MRR) is increased with respect to the increase of the open voltage, the pulse duration, the amplitude of ultrasonic actuation, the discharge current, and the decrease of the wall thickness of electrode pipe; and (b) the surface roughness is increased with respect to the increase of the open voltage, the pulse duration, and the discharge current. Based on experimental results, a theoretical model to estimate the MRR and the surface roughness is developed. UEDM in gas is a useful process. Its material removal rate (MRR) is nearly twice as much as EDM in gas, though is less than that of conventional EDM. UEDM in gas is affected by at least five factors: open voltage, discharge current, discharge duration, the wall thickness of the pipe electrode, and the amplitude of the ultrasonic actuation. Among these factors, the discharge current and the pulse duration are the most significant. Though, the wall thickness of the pipe electrode is also important, as it affects removal of molten work piece material. In the process of UEDM in gas, the increase of MRR is at the expense of surface roughness.

S. K. Saha and S. K. Choudhury et.al [6] studied parametric Analysis of the process has been performed with tubular copper tool electrode and mild steel work piece. Experiments have been conducted using air as the dielectric medium to study the effect of gap voltage, discharge current, pulse-on time, duty factor, air pressure and spindle speed on material removal rate (MRR), surface roughness (Ra) and tool wear rate (TWR). First, a set of exploratory experiments has been performed to identify the optimum tool design and to select input parameters and their levels for later stage experiments. Empirical models for MRR, Ra and TWR have then been developed by performing a designed experiment based on the central composite design of experiments. Response surface analysis has been done using the developed models. Analysis of variance (ANOVA) tests were performed to identify the significant parameters. Current, duty factor, air pressure and spindle speed were found to have significant effects on MRR and Ra. However, TWR was found to be very small and independent of the input parameters. Flow characteristic of air in the inter-electrode gap affects the MRR and the surface roughness (Ra). There exists an optimum number of air-flow holes (in the tool) for which the MRR is highest and the Ra is lowest. From the designed set of experiments based on CCD it was found that discharge current, duty factor, air pressure and spindle speed are the significant factors which affect MRR and MRR increases with an increase in any of these factors. From CCD experiments it was found that except for gap voltage all other input parameters (discharge current, pulse-on time, duty factor, air pressure and spindle speed) have significant effect on Ra. Ra values decrease with a decrease in the values of current and duty factor. Also, Ra values decrease with an increase in the values of air pressure and spindle speed.

Grzegorz Skrabalak, Jerzy Kozak et. al. [7] studies on Dry Electrical Discharge Machining results of simulation and mathematical modelling of the material removal rate of electro discharge milling process with compressed air as dielectric. There are also presented basic characteristic of the DEDM milling process and comparison of this green machining method with kerosene based EDM milling. Fig.2 shows Material removal rate comparison of EDM in kerosene and Dry EDM. Fig.3 shows Comparison of TWR/MRR coefficient for kerosene and dry EDM milling

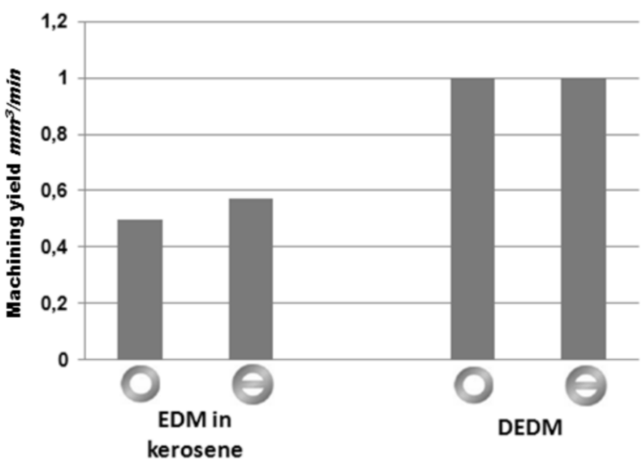

Fig. 2: Material removal rate comparison

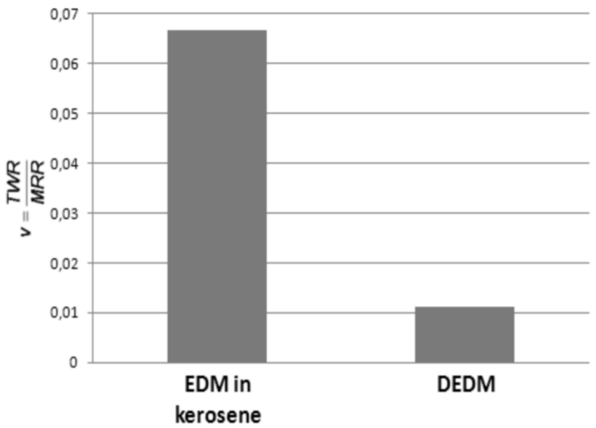

Fig. 3: Comparison of TWR/MRR coefficient for kerosene and dry EDM milling

The method is useful not only when thin-walled electrodes are used, like during tests run in Japan, but also when the active area of the electrode is relatively big (in comparison to the gas supply channels) – more than 50%. DEDM milling process may be very useful especially for micro machining. Due to the tool wear ratio it is more precise than EDM milling in kerosene, what is important aspect in case of machining in micro-scale. Also process of preparing tool paths is much easier, as the tool wear is negligible.

Yusliza Yusoff, Mohd Saliin Ngadiman, Azlan Mohd Zain et. al. [8] studied an overview on NSGA-II optimization techniques of machining process parameters. NSGA-II is a well-known, fast sorting and elite multi objective genetic algorithm. Process parameters such as cutting speed, feed rate, rotational speed etc. are the considerable conditions in order to optimize the machining operations in minimizing or maximizing the machining performances. Unlike the single objective optimization technique, NSGA-II simultaneously optimizes each objective without being dominated by any other solution. NSGA-II as part of MoGA is a popular and reliable technique that can be used in optimizing the process parameters of multiple machining performances. It can be observed that; (i) ANN, GP, fuzzy, regression analysis are some of the methods used in modeling the machining performance prediction, (ii) NSGA-II is a multi-objective optimization tool that can meet the requirements of the machining process in finding set of solutions based on combination of suitable variables.

R. Rajesh and M. Dev Anand et. al. [9] studied on The Optimization of the Electro-Discharge Machining Process Using Response Surface Methodology and Genetic Algorithms. A proper selection of machining parameters for the EDM process is dependent on operator's technologies and experience because of numerous and diverge range. Machining parameters provided by machine tool builder cannot meet operator's requirement. To solve this task, multiple regression model and modified Genetic Algorithm model are developed as efficient approaches to determine the optimal machining parameters in electric discharge machine. In this paper working current, working voltage, oil pressure, spark gap, Pulse On Time and Pulse Off Time on Material Removal Rate (MRR) and Surface Finish (Ra) has been studied. Empirical models for MRR and Ra have been developed by conducting a designed experiment based on the Grey Relational Analysis. Genetic Algorithm (GA) based multi-objective optimization for maximization of MRR and minimization of Ra has been done by using the developed empirical models. Metal removal rate and surface roughness are combined to have a single objective as grey relational grade by the application of grey relational analysis. Linear regression model have been developed to map the relationship between machining parameters and output responses. Finally the optimal conditions obtained by GA as. i.e., current at 3 A, voltage at 78 V, gap at 0.35, flow rate at 1, pulse ON as 1 and pulse OFF as 8 for maximizing MRR and minimize the surface roughness simultaneously among the experimental data.

Ramezan Ali Mahdavi Nejad et. al. [10] studied that Silicon Carbide (SiC) machining by traditional methods with regards to its high hardness is not possible. Electro Discharge Machining, among non-traditional machining methods, is used for machining of SiC. The present work is aimed to optimize the surface roughness and material removal rate of electro discharge machining of SiC parameters simultaneously. As the output parameters are conflicting in nature, so there is no single combination of machining parameters, which provides the best machining performance. Artificial neural network (ANN) with back propagation algorithm is used to model the process. A multi-objective optimization method, non-dominating sorting genetic algorithm-II is used to optimize the process. Effects of three important input parameters of process viz., discharge current, pulse on time (Ton), pulse off time (Toff) on electric discharge machining of SiC are considered. Experiments have been conducted over a wide range of considered input parameters for training and verification of the model. A Pareto-optimal set has been predicted in this work. Various ANN architectures have been studied, and 3-5-5-2 is selected. Material removal rate and surface roughness have been optimized as objectives by using a multi-objective optimization method. Non-dominating sorting genetic algorithm-II and finally Pareto-optimal sets of material removal rate and surface roughness are obtained.

IV. CONCLUSION

1) Fewer tool electrodes are required in dry EDM due to lower tool wear. The total machining time for dry EDM may then be lower than die-sinking EDM.
2) In the process of UEDM in gas, the increase of MRR is at the expense of surface roughness.
3) It was found that discharge current, duty factor, air pressure and spindle speed are the significant factors which affect MRR and MRR increases with an increase in any of these factors. Ra values decrease with an increase in the values of air pressure and spindle speed.
4) NSGA-II is a multi-objective optimization tool that can meet the requirements of the machining process in finding set of solutions based on combination of suitable variables.
5) Genetic Algorithm (GA) based multi-objective optimization for maximization of MRR and minimization of Ra has been done by using the developed empirical models.
6) Material removal rate and surface roughness have been optimized as objectives by using a multi-objective optimization method.

V. FUTURE SCOPE

For Dry EDM Ceramic materials both conductive and nonconductive materials not so much work is carried out. So, for future we can consider this material for research work in Dry EDM. For analysis and optimization we can use soft computing techniques like GA, Fuzzy Logic, and ANN are carried out.

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