A Review on Powder Mixed Electro Discharge Machining

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Abstract: Electrical discharge machining (EDM) is a good machining option for manufacturing geometrically complex or hard material parts. Parts those are extremely difficult-to-machine by conventional machining processes. During machining the heat intensity from the spark melts a part of the workpiece. However, the technological capability of the process has limited its application when the specification of the part surface quality imposes polished and mirror-like characteristics. The addition of powder particles in suspension in the dielectric modifies some process variables and creates the conditions to achieve a high surface quality in large areas. Recently, EDM researchers have discovered a number of ways to improve the efficiency in sparking with some unique experimental concepts that is different from the EDM traditional sparking phenomenon. Therefore powder mixed electro discharge machining (PMEDM) process is more efficient than conventional electro discharge machining process.

Keywords: EDM (Electric Discharge machining), PMEDM (Powder Mixed Electro Discharge Machining),MRR (Material Removal Rate), SR (Surface Roughness)

I. INTRODUCTION

Electrical discharge machining (EDM) is one of the most widely used non-conventional materialremoval processes. It's most unique feature being the use of thermal energy to machine electrically conductive parts irrespective of hardness has been its most distinguishing advantage in the manufacture of mould, die, automotive, aerospace and surgical components. In EDM there is no direct contact between the electrode and the workpiece eliminating the mechanical stresses, chatter and vibrations during machining. Electrodes as small as 0.1 mm can be used to drill holes. [1]. The root of EDM can be drawn as far back as 1770 when an English chemist Joseph Priestly discovered the erosive effect of electrical discharges or sparks [2]. Though, it was only in 1943whenLazarenko[3] used the destructive properties of electrical discharges for machininguse.

It was in the 1980s with the coming on of computer numerical control (CNC) in EDM that brought about major advances in refining the efficiency of the machining processes. CNC has facilitated total EDM, which includes an automatic and unattended machining from loading the electrodes in the tool changer to a finished polished machined surface[4].

II. EDM

A.EDM Process

The material removal mainly takes place due to erosion mechanism where electrical energy and turned into thermal energy through a series of discrete electrical discharges occurring between the electrode and workpiece immersed in a dielectric fluid [5]. This thermal energy between the tool and the workpiece creates a plasma channel between the anode and cathode [6] at a very high temperature of about 20,000 °C therefore substantial heating and melting of work material at the surface of each pole. A pulsating direct current supply occurring at the rate of approximately 20,000–30,000 Hz is supplied to the machined [7] which when turned off, the plasma channel breaks down. Therefore, causing a sudden reduction in the temperature allowing the dielectric fluid to flush the molten material from the pole surfaces in the form of debris.The volume of material removed per discharge is typically in the range of 10_6–10_4 mm3 and the material removal rate (MRR) is usually between2 and 400 mm3/min [1]. The shape of electrode defines the area in which the spark erosion will occur,the accuracy of the produced partis very high compared to conventional machining processes [8].

B.EDM Applications

Electro Discharge Machining allows tool steels to be treated to full hardness before machining, therefore avoiding the problems of dimensional variability, which are characteristic of post-treatment [9].

In Electro Discharge Machining there is no induced mechanical stresses during machining, therefore it provides an extra advantage in the manufacture of intricate and complex products. Wenget. al.,[10] conducted several successful experiments which included an electrode of diameter 50 µm r and a multi-electrode for the batch production of parts. The method considerably reduces the production time and costs of fabricating both the electrodes and parts.

The reduction in the size of the additive of the powder has significantly given rise to the research in this field. Through micro-EDM not only holes in micron range also shafts as small as 5 µm in diameter and complex three-dimensional (3D) microcavities can be machined [28]. Masuzawa et al. [11–13] made several successful attempts machining microparts such as micro-nozzles and micro-cavities using micro-EDM. Micro-EDM has also been used as an alternative method for producing photo-masks used in the integrated circuit (IC). Ishida et. al.,[14] recently suggested a trajectory EDM technique enabling the electrode to flow along a smooth trajectory or path, while performing EDM to solve the machining problems of water-cooling channels used in moulds or manifolds. Other attempts [15,16] have also been made on trajectory EDM but this requires special apparatus or complex control to develop the trajectory motion of electrode.

By the development ofmodern composite materials in the last era has led to agrowth of EDM applications. Yan et al., [17] carried out surveys in the various machining processes on metal matrix composites (MMC) such as Al2O3/6061Al composite using rotary EDM coupled with a disc-like electrode. The possibility of machining ceramic–metal composite steel plate coated with WC–Co (tungsten carbide–cobalt) using plasma spraying was also inspected [18].

III. LITERATURE REVIEW

Jeswaniet al.,[19] in 1981 studied the effect of addition of graphite powder to kerosene used as dielectric fluid in electro discharge machine. Mild steel work pieces with copper electrodes were taken. The results reveal that the addition of about 4g per litre of kerosene increase the material removal rate by 60% and the tool wear rate by 15%. Material removal rate in electro discharge machining particularly in the lower spark energy range (1-500ml) can be increased. Also a 30 percent reduction in the breakdown voltage was observed. Ming et.al.,[20] in 1995 presented the effect of additives in kerosene as dielectric fluid for EDM. A 20mm diameter copper electrode was used as a tool, a max current of 30 Amperes was supplied with a pulse width of 1-200µs. The test results showed that the additives can increase material removal rate and improve the quality of surface finish of the work especially in the mid-finish and finish machining. Additives to kerosene can decrease the loss of alloy elements, increase the micro hardness, make the molten layer thinner and reduce cracks. Wonget. al.,[21] in 1997 showed the near mirror finish phenomenon in EDM when fine powder is introduced into the dielectric fluid. Machining on various types of steel with different powder suspension at a peak current around 1Ampere.Copper electrode was used as tool and AISI-01 steel as work piece. Close observation showed overlapping re-solidified discs with smooth rims. Appropriate setting of electrode polarity and pulse parameters and the correct combination of the work piece material and powder characteristics have significant influence on the mirror like finish conditions. Chowet. al.,[22] in 1998 studied the effect of addition of powders such as silicon carbide and aluminium in kerosene for micro slit EDM. Tool electrode used is a copper diskette. The results were such that addition of silicon carbide and aluminium permits extension of gap between the work piece and the electrode thus increasing debris removal rate and material removal rate. Also silicon carbide produces better material removal depth than aluminium. Zahoet. al.,[23] in 2002 showed Powder EDM for rough machining MD21 Numeric Controlled EDM with red copper electrode over steel work piece was used. The dielectric used was a working fluid from Mobil Corp. It showed that powder mixed electro discharge machining makes discharge breakdown easier. Efficiency can be increased by proper discharge parameters like increasing peak current, reduction in pulse width. Also, PMEDM makes discharge breakdown easier.

Shabgardet. al.,[24] in 2009 made a study the combination of the electrical discharge machining (EDM) with ultrasonic vibrations to improve the machining efficiency. The work piece used was AISIH13 Tool Steel. The parameters such as discharge peak current and pulse duration were changed to observe their effect on the material removal rate (MRR), relative tool wear ratio (TWR) and surface roughness. An EDM with a servo control generator was used. From the experimental result it can be concluded that ultrasonic vibration of the work piece can significantly improve the stability of process and reduces the inactive pulses. From the results it was found that ultrasonic assisted EDM (US-EDM) is effective in attaining a high material removal rate (MRR) in finishing. Kumaret. al.,[25] in 2011 analysed the machining characteristics in additive mixture electric discharge machining of nickel based super alloy Inconel 718. Po Aluminium was taken as the powder additive with red copper electrode. Aluminium powder particles of concentration 6g/l in additive EDM produce maximum machining rate and minimum surface roughness. It was concluded that it is effective option for machining Inconel 718 with copper electrode with negative polarity.

Futuraniet. al.,[26] experimental analysis showed deposition of lubricant surface by electrical discharge machining with molybdenum disulphide powder suspended EDM oil. A die-sinking electrical discharge machine was used. During EDM with MoS_2suspended in the working oil it was concluded thatMoS_2 could be deposited on metals which melting point is lower than MoS_2. It was found that there was dispersion of lubricant duration due to the uneven concentration of MoS_2. Bhattacharya et. al.,[27] in 2013 made studies on surface characterization and material migration during surface modification of die steels with silicon, graphite and tungsten powder in EDM process to investigate the effect of powder mixed with the dielectric and other process parameters on the surface roughness and surface properties using Taguchi's design of experiment. The experiments were done on three commonly used die steels high carbon high chromium (HCHCr), H11 hot die steel and AISI 1045 steel. The work pieces were machined in an EDM using brass, copper, tungsten copper with Si, W and graphite powders mixed in dielectric. Addition of powders in dielectric improved the surface finish of the machined surface significantly. Parameters such as powder concentration, current and pulse on time were observed to the major significant factors affecting surface roughness. It also showed that the brass electrode and tungsten powder resulted in good surface finish whereas W-Cu electrode and W powder gave higher micro hardness. Molinettiet. al.,[28] in 2015 showed Surface modification of AISI H13 tool steel with silicon or manganese powders mixed to the dielectric in electrical discharge machining process. This study was carried out to find out the use of manganese and silicon powders suspended in dielectric fluid during EDM machining of AISI H13 tool steel. The addition of Silicon and Mangenese to the dielectric fluid makes more uniform resolidified layer when compared to conventional EDM process. Aresolidified layer free of micro-cracks and hardness increase of roughly 40 % due to the use of PMEDM. The surface roughness was drastically improved with silicon and manganese powders.

Md. Karim Baig and Dr. N Venkaiah [29] carried out parametric optimization using GRA method of WEDM for HastelloyC276. Experiments were carried out on electronica Wire EDM machine, with the work piece as HastelloyC276. The wire used was a Brass wire of 0.3mm diameter which was coated with zinc and is also known as “stratified Brass wire”. Dielectric fluid used is deionized water. From the analysis, the discharge current was found to be the most significant factor affecting the responses, MRR and Kerf.

In 2012 Khalid Hussain SYED [30]conducted experiments on the performance of electrical discharge machining using aluminium powder suspended distilled water. The experiments were done on a die sinking EDM C-425, Electronica Industries, India. A separate system was designed and fabricated for the recirculation of the dielctric.W300 steel was chosen as the work material. Copper was chosen as the tool electrode material. The experiments were conducted with powder mixed distilled water as dielectric. The powder selected was aluminium with particle size of 27 μm. The dielectric was circulated at the work-tool interface by means of an external jet. It was concluded that maximum MRR is obtained at a high peak current of 12 A.

Narumiya et al.,[31] in 1989 carried out EDM by powder suspended working fluid using aluminium graphite and silicon powders materials. The concentrationof the powder was ranged between 2gm/l to 40gm/l. Their conclusion showed that the discharge gap distance increases with the concentration of the powder. The best surface finish was obtained at low powder concentration.

Multiple researches have also been reported on the material removal mechanism (MRM) by the movement of material elements between the workpiece and electrode. Soni and Chakravertiet. al., [32] showed that an appreciable amount of elements diffused from the tool electrode to the workpiece material and viceversa. These migrated elements can either be in solid, liquid or gasesous state and is alloyed with the surface in contact by going through a solid, molten or gaseous-phase reaction [33]. The types of electrode, workpiece elements and the dielectric fluid considered significantly affect the MRR [34]. It was also found out that by reversing the polarity of sparking modifies the material removal rate with a large amount of electrode material being deposited on the workpiece surface [35].

An efficient MRR improvement technique has been made recently by revising the principle

of EDM of single discharge for each electrical pulse. Kunieda and Muto in 2000 [36] experimented on a multi-electrode discharging system. The design of multiple electrodes was based on the Mohri et al. [37] which are electrically insulated.The TWR and energy efficiency when using a multiple electrode were observed to be better than the traditional EDM but minimum changes were seen in terms of surface roughness (SR).

IV. DISCUSSION AND FUTURE DIRECTION OF EDM

Many researchers have contributed in different sectors but due to complicated nature of the EDM process, lots of works are still required to be done. Mostly, published works are mainly based on research areas such as optimising the process variables, Improving the performance measures, monitoring and control of the process and EDM developments like multitool electrode, hybrid EDM’s . Researchers have shown that PMEDM machining can clearly improve the MRR and surface quality and obtain mirror surface effects. Regardless of results, PMEDM process is used in industry at very low pace. The reasons being the new matters of this new development, including the machining mechanism which is still not well understood.Thus, the EDM process needs to be constantly revitalised to remain competitive in providing an essential and valuable role in the tool room manufacturing of part with difficult-to-machine materials and geometries.

From the above study it can be drawn as follows:

1. PMEDM facilitates the discharge breakdown, widens the discharge gap also enlarges the discharge passage and forms evenly distributed cavities.
2. The efficiency of the PMEDM can be increased by selecting the proper parameters with better MRR and SR compared to traditional or conventional EDM.
3. Totally Burr free & no stresses produced in work piece.

4. Material removal rate is maximumaffected by the increase of peak current.

5. Tool wear rate in PMEDM is smaller as compared with the conventional EDM Process.

Although PMEDM process is an efficient alternative to traditional EDM, still problems can be encountered in PMEDM as well such as electrode wear, removal of the machined metal debris from the recirculating powder mixed dielectric.

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