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Powder Mixed Electrical Discharge Machining

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***Abstract*: Electrical discharge machining in the recent years has emerged as a very advanced technique for machining electrically conductive materials that are very hard to machine. Edm was developed as a electro- chemical process to overcome challenges faced by conventional methods like shaping extremely hard, complex and intricate profiles, shapes and contours but still had its own set of limitations. With time advancements were made to improve this process by adding ceramic powder to dielectric fluid. This paper reviews powder mixed edm, the effect of powder and how the optimization of parameters leads to subsequent improvement in metal removal rate, surface finish and tool wear rate using inconel 718**

***Keywords*: EDM, MRR, SR, TWR, PMEDM**

1. Introduction

EDM is a advanced revolutionary technique of machining initially developed in the 1940s to achieve high quality and efficiency to produce sophisticated and intricate profiles even on extremely tough materials it uses the corrosive effect of electrical charges to remove material from work piece which makes it a non-contact process. Since there is no contact force applied by tool on work piece, there is no chatter, mechanical stress, vibrations or friction loss. It finds wide applications in the die cavity molding, precision requiring parts automotive, medical and aerospace industry. Powder mixed edm is developed as an advancement to edm to overcome shortcomings regarding metal removal rate, surface finis and tool wear rate. In this process a suitable powder is mixed in the dielectric fluid. Qualities like electrical conductivity, thermal conductivity, density, hardness, suspension properties and size along with other parameters are taken into account.

2. Mechanism of PMEDM

Powder is mixed in the dielectric fluid and mixed. The powder stays in the fluid in suspended form. Mixing of the powder affects insulating strength and spark gap. A voltage is applied and an electrical field is generated which causes the powder to move in a random zig zag motion due to high energy in them. At this point the tool acts as anode, the work piece as cathode and the suspended powder and Fluid as medium to pass off spark discharges and a stream of high frequency spark is generated. Here the bridge effect takes place where chain like structures are formed reducing or bridging the gap the gap between the tool and the work piece. The spark has erosive nature and the work piece is thus machined. A plasma channel is formed due to sparking which gets enlarged on mixing powder. Prolonged sparking causes the temperature in the channel to reach 8000 to 12000 degree Celsius. The spark frequency increases with frequency of electric discharge and consequent metal removal rate increases .the powder is mixed with a stirring system and circulated with the help of a pump to uniformly distribute it throughout the dielectric fluid. Proper distribution allows uniform distribution of charge and uniform metal removal. Volume of material removed per charge is also low (about 10^-6 to 10^-4) which allows for a very good surface finish. The material removal is from both the tool as well as work piece but non-contact process allows for lower tool wear rate.

A. Particular process parameters

In PMEDM some particular process parameters influence the performance parameters. These are machining inputs which are controllable and which decides the circumstances in which machining is performed.

1) Peak Current (Ip)

It is the maximum current available for each pulse from the powder supply. The surface area of the cut controls it. At the cost of surface finish and tool wear high current generate high MRR. Peak current is also responsible for accuracy of machining, because it affects Tool Wear.

2) Gap Voltage

The voltage between gap of the electrode and work piece is called gap voltage. Because of higher voltage the gap between electrode and work piece increases and it helps to stabilize the machining and it increase MRR.

3) Pulse Duration (Ton)

This is the period of time (μs) the current is allowed to flow per cycle. During this period the dielectric is ionized and sparking occurs. It is the productive regime of the spark cycle during which current flows and machining is done. The amount of material removal is directly proportional to the amount of energy applied during this time. Although the MRR increases with tonnage, the higher spark energy results in rough surfaces.

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4) Pulse Interval

It is the period between two consecutive pulse-on times. The supply voltage is cut off during the pulse-off time. During this period the dielectric de-ionizes and gains its strength. This time allows the molten material to solidify and flow out of the arc gap. The pulse-off time should be minimized as no machining takes place during this period. However, too little Toff leads to process instability.

5) Polarity

Polarity refers to the ability of the work piece with respect to the tool. Straight into or the positive polarity work piece is positive, while the work piece in reverse polarity is Negative. In direct polarity, the quick reaction of electrons generates more energy at the anode. (Of a work piece) as a result of which important material is removed. However, high equipment wear occurs. With a long pulse duration and positive polarity due to the high mass of the ions. In general, the selection of polarity is determined experimentally based on a combination of Work piece material, tool material, and current density and pulse duration.

6) Dielectric Fluid

The dielectric fluid in EDM performs three important functions. First the function of the dielectric fluid is to insulate the inter electrode gap and after breaking at the appropriate applied voltage, the conduction of the flow of current. The second task is to remove debris from the machined area, and ultimately, acts as a dielectric coolant to aid in heat transfer from the electrodes. The most commonly used dielectric fluids are Hydrocarbon compounds such as light transformer oil and kerosene.

7) Electrode Gap

Inter electrode gap is an important factor for spark stability and proper flushing. The most important requirements for good performance are interval stability. And the response speed of the system, the presence of backlash is especially undesirable. The response speed must be high to respond to short circuit or open gap conditions. Gap width is not directly measurable, but can be estimated from the average gap voltage. The equipment servo mechanism is responsible for maintaining the working interval at a set value. Mostly Electro mechanical (DC or stepper motors) and electro hydraulic systems are used, and are typically designed to respond to average lag voltage.

8) Powder

The powder is added in the dielectric fluid because it increases MRR and decreases TWR and it improve the surface finish very good. The powder should be electric conductive in nature and non-magnetic in nature, it should have good suspension capability and good thermal conductivity. The size of the powder used are micro to nano particle. And the powder concentration should be between 1g/l to 8g/l.

B. Performance parameters

1) Metal Removal Rate (MRR)

Material removal rate (MRR) is the amount of material removed per time unit, directly aiming at the process productivity. In roughing operations and the production of large batches, this needs to be maximized.

MRR = Weight loss of Work piece x 1000/ Density x Machining Time

2) Tool Wear Rate (TWR)

Tool wear is an important factor because it affects dimensional accuracy and the shape produced. Tool wear is related to the melting point of the materials. Tool wear is affected by the precipitation of carbon from the hydrocarbon dielectric on the electrode surface during sparking.

TWR = Weight Loss of Tool x 1000/ Density x Machining Time

3) Wear Ratio

The electrode wear ratio is the most commonly used terminology for getting information about electrode wear and is defined as the volume of metal lost from the tool electrode divided by the volume of metal removed from the work piece. High tool wear rates result in inaccurate machining and considerably add to the expense since the tool electrode itself must be first accurately machined. To reduce the influence of the electrode wear, it is necessary either to feed electrode larger than the work piece thickness in the case of making through-holes, or to prepare several electrodes for roughing and finishing in the present state of technology.

4) Surface Roughness

Surface roughness is defined as the shorter frequency of real surfaces relative to the troughs. If you look at machined parts, you will notice that their surfaces embody a complex shape made of a series of peaks and troughs of varying heights, depths, and spacing.

5) Recast Layer Thickness

The spark produced during the EDM process melt the metal's surface, which then go ultra-rapid quenching, A layer forms on the work piece surface defined as recast layer thickness after solidification. It usually situated at the heat affected zone.

3. Literature Gap

There is a limitation to use a conventional machining process to cut hard materials, non-conventional machining such as electrical discharge machining (EDM) is one of the preferred techniques in dealing with these materials such Inconel 718 or Inconel 625 or Ti-6Al-4V or any other material. EDM has the capability of machining intricate profiles and materials which are difficult to cut. EDM has been broadly applicable for manufacturing of complex cavities in moulds and dies, aerospace, automotive and surgical components and some others which are some of its applications. Several advancements in this field have been made in the past and still focusing to enhance the machining performance. PMEDM (Powder mixed electrical discharged machining) is a well-established machining option for improving the MRR, TWR, SR, SF etc. Many researchers have attempted different techniques such as Ultrasonic Vibration Assisted EDM, Rotary

Table 1
Literature review

Author	**Powder**	**Tool Material**	**W/P Material**	**Input Parameter**	**Output Parameter**	**Year**
Ayanesh Y. Joshi a, Anand Y. Joshi b	Graphite	Copper	Titanium	Discharge current, surfactant, powder concentration	MRR,SR, TWR, RLT	2015
Kamlesh Paswan, A. Pramanik	Graphite	Copper	Inconel 718	Peak current, pulse on, Gap voltage	MRR, TWR, Surface Roughness	2020
Rafał Swiercz and Dorota Oniszczuk-Swiercz	Reduced graphene oxide (RGO) flakes	Copper electrode, aluminium	55NiCrMoV7	Discharge current, pulse time	MRR	2019
Kashif Ishfaq, Saqib Anwar	Graphene	Aluminium, copper, brass	Ti-6Al-4V	voltage, current, polarity, pulse, time on	MRR, TWR	2020
Asarudheen Abdudeen , Jaber E. Abu Qudeiri	aluminum, chromium, graphite, silicon, copper, and silicon carbide	Copper	carbides, stainless steels, hastalloys, nitralloys, waspalloy, nomonics	Pulse-on time, Pulse-off time, Servo voltage, Peak current, Gap voltage, Dielectric flow rate, Wire feed rate	MRR, TWR , SR	2020
Ansar Kareem, Thanveer Ahammed	Aluminum	Copper	W300 Die Steel	Peak current, Pulse on time, Powder concentration, and polarity	MRR, EWR, SR, WLT	2020
Aiman Ziout, Asarudheen Abdudeen , Jaber E. Abu Qudeiri	Nickel micro powder	copper	EN-19	Peak current, Duty cycle, Electrode angle, Powder concentration	Mrr, TWR	2020
Thrinadh Jadam, Santosh Kumar Sahu, Saurav Datta	MWCNT Multi-Walled Carbon Nanotubes	COPPER ELECTRODE	INCONEL 718	Peak current, pulse off time , pulse on time	MRR, TWR, SR	2020
Dipraj Banik ,Rahul , Subhankar Bhattacharjee, Biswajit Debnath	Chromium	Copper	Inconel 718 Super Alloy	peak current (IP), open voltage (Vg), pulse-on-time(Ton) & duty factor(τ)	MRR, EWR, SR	2019
F.Q. Hu et al.	Al powder concentration: 35 g/L Al particle sizes	copper	SiCp/Al composite	Current: 0.5 A; pulse duration: 12 s; pulse interval time : 40 s; gap voltage: 50 V	SR, corrosion resistance, wear resistance	2013
S. Ahmad et al.	nano Alumina (Al2O3) powder	Copper tungsten	Inconel 718	Discharge current, Ip Pulse on time, ton Pulse off time, toff Powder concentration, Cp Voltage, V Electrode polarity Dielectric medium Cutting depth	MRR, SR	2018
S. PATEL ET AL.	AL Powder	Copper tungsten	Inconel 718	Sparking Gap Peak Current Pulse on time Duty Factor Tool Rotation-300 RPM Slurry Concentration	MRR, TWR, SR, HD, SEM, EDX	2018
Gangadharudu Talla, S. Gangopadhyay, and C.K. Biswas	AL, Graphene and SI powder	Copper	Inconel 625	Powder concentration , Peak current , Pulse time ,Duty cycle, Gap voltage	. Least ROC and highest surface hardness, n MRR, surface finish	2015
K.Karunakaran1and M.Chandrasekaran	Al2O3, SiC and graphite powder	Silver coated Electrolyte copper Electrode	Inconel 718	Current (A) Pulse On Time (μs) Pulse Off Time (μs)	MRR, TWR and SR	2017

Assisted EDM, Magnetic Assisted EDM, and And Ultrasonic with Rotary Assisted EDM, Gas Assisted EDM, Cryogenic Assisted EDM, and Powder Mixed EDM. However, some of them are long time consuming of machining process including traditional EDM that related to time and cost was almost the top issue to the manufacturing industries. Powder mixed electro-discharge machining (PMEDM) is a promising technique which reduces the limitations and improves the machining performance of traditional EDM. Over the last two decades, work has been done in the field of PMEDM on different process performance. However, the data can be said insufficient about variability of process parameter for a particular powder to a known workpiece and electrode so as a result more research is needed with different selections. Role of different powders on study of various properties such as corrosion resistance, fatigue resistance, micro hardness, microstructure, and wear resistance has been taken up by very few researchers. Number of issues need to be addressed in future for implementation of this modified process of machining. There is an urgent need to work out on this area.

4. Conclusion

The reviews on the state of art, studies on the powder mixed dielectric fluid in EDM processes lead to the following conclusions.

1. EDM has brought many improvements in machining process in recent years. The capability of machining intricate parts and hard material has made EDM as one

of the most popular machining processes.

2. It can be concluded from this review that PMEDM holds a bright promise in application of EDM, particularly with regard to process productivity and surface quality of workpiece. As such, extensive study is required to understand mechanics of machining and other aspects of PMEDM.
3. Performance parameters like Metal Removal Rate (MRR), Tool Wear Rate (TWR), Wear Ratio, Surface Roughness, Recast Layer Thickness and process parameters like peak current (Ip), gap voltage, pulse duration (Ton), pulse interval, polarity, dielectric fluid, electrode gap, powder, were studied thoroughly.
4. This review reveals that, with a specific increase in concentration of powder in the dielectric fluid, the MRR and SF will increase. Increasing the concentration of powder in the dielectric fluid beyond the certain optimum concentration of particles in the dielectric, short-circuit discharges occur. From this analysis, it can be concluded that PMEDM holds a brilliant promise in the application of EDM, in particular, regarding process efficiency and work piece surface quality. Therefore, an extensive study is required to understand the machining mechanics and other aspects of PMEDM and will be performed as future research.
5. PMEDM comes with a vast future scope of it and we have explored all the parameters and data related with powder mixed EDM process. And the results obtained are far much better than the past.
6. So, to help the future researchers to understand this concept thoroughly and research the process parameters further in more details to get more improvements the review paper was prepared.

5. Figures

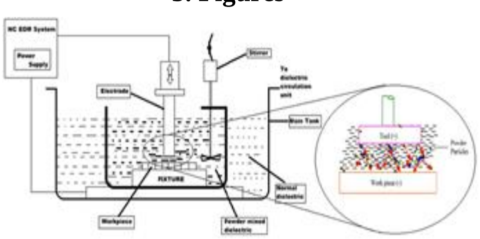

Fig. 1. Schematic diagram of machining set-up and principle of powder-mixed EDM

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