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Analysis of machining parameters of aluminium power mixed EDM process

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ABSTRACT

Scientifically emerging industries like automotive, defense, aerospace, electronics, nuclear power, metallic moulds and dies require materials of high strength, high-temperature resistant alloys like carbides, super alloys, haste-alloys etc. Manufacturers strive hard to produce these components at lower cost and of esteem quality as they have a direct impact on the profit earned by the firm. Hence, the productivity can be improved by increasing the material removal rate (or) by reducing the machining time of the product. Addition of a fine conductive powder to the dielectric fluid decreases its insulating strength and consequently increases the inter-electrode space causing an easy removal of the debris. The process variables of PMEDM play a considerable role in material removal mechanism. Performance of the PMEDM process depends upon characteristics like powder type, concentration, particle size, and electrode area and work piece constituents. As a result, the process becomes more stable, thereby, improving the material removal rate (MRR) and surface finish. Moreover, the surface develops high resistance to corrosion and abrasion. In this study, we have chosen the OHNS (Oil Hardened Non-Shrinking) die steel as work piece material. A copper electrode and brass electrode with a diameter of 10 mm were used to cut the work piece in EDM. Commercial kerosene has been chosen as a dielectric fluid. The consequence of the Machining parameters such as Pulse ON time, Pulse OFF time and current over the Machining time and Surface Roughness has been analyzed. The interaction study is made by Response Surface Methodology.

Keywords: *Electrical Discharge Machining, Aluminum Power, OHNS Steel, Parameters Optimization.*

1. INTRODUCTION

Electrical discharge machining (EDM), also known as spark machining, is a manufacturing process whereby a desired shape is obtained by using electrical discharges (sparks).The material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. Electrical discharge machining is primarily used for hard metals or those that would be very difficult to machine with traditional techniques. One of the latest advance methods for improving the capabilities of EDM process is the mixing of a suitable material in powder form into the dielectricfluid. This process is called powder mixed EDM (PMEDM).Addition of a fine conductive powder to the dielectric fluid decreases its insulating strength and consequently increases the inter-electrode space causing an easy removal of the debris. The inter-electrode spark gap is filled up with fine metal powder particles, and the gap distance between tool and the work piece increases. The powder particles get energized and the grains come close to each other under the sparking area and form groups. Under the influence of electrostatic forces, the powder particles arrange themselves in the form of chains at various places under the spark area. The chain formation helps in bridging the gap between both the electrodes. Due to the bridging effect, the gap voltage and insulating strength of the dielectric fluid. The easy short-circuit takes place, which results premature explosion in the gap. Thus a series of discharges starts under the electrode area. Due to the increase in the frequency of discharging, the faster sparking within a discharge takes place, which causes faster material removal from the work piece surface. At the same instance, the mixed powder alters the plasma channel. The plasma channel gets enlarged. The electric density decreases; hence, sparking is uniformly spread among the powder particles. Hence even and more uniform distribution of the discharge takes place, which causes uniform material removal from the work piece. This results in enhancement in dimensional accuracy. The process variables of PMEDM play a considerable role in material removal mechanism. Performance of the PMEDM process depends upon characteristics like powder type, concentration, particle size, and electrode area and work piece constituents.

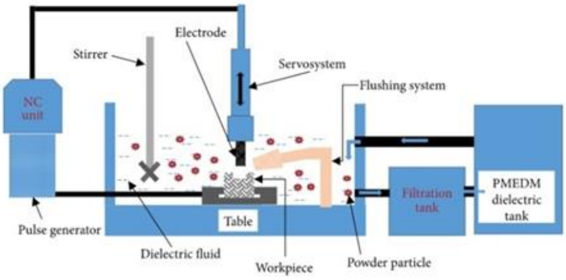

Fig.1: Schematic diagram of machining set-up and principle of powder-mixed EDM

2. LITERATURE REVIEW

M.A. Razak, A.M. Abdul-Rani et.al [1] (2016), used Taguchi method to analyze the effect of EDM input parameters for machining Biodegradable AZ31 Magnesium alloyon microstructure changes. The results show thatthe optimum EDM parameters to machine AZ31 magnesium alloy are 47 A peak current, 80 V voltage, 16 µs pulse on-time and 512 µs pulse off-time.Finally, even though EDM is excellent in machining intricate shapes with tight tolerance and burr-free, the undesirable cracks and craters were found on the machined surface area.In recent years, research works have been initiated to improve the efficiency of EDM process using powder mixed EDM method (PMEDM) which has the potential to reduce the formation of cracks and craters during EDM process.

G. Bharath Reddy, V.S.P. Vamsiet.al [2] (2015), conducted a parametric analysis on powder mixed electric discharge machining of various steels using Taguchi method.The conclusions made from the experiment are adding aluminium metal powder in dielectric fluid generates superior surface finish than that of the addition of copper metal powder and without the addition of metal powder. Further, the material removal rate is mainly affected by Peak current and pulse on-time and type of metal powder as an additive. At the higher value of peak current, greater is the MRR.The Surface roughness of the HCHCr steel is superior compared to EN-31 steel.

ShaliniMohanty , Ankan Mishraet.al [3] (2017), says that an experiment on multi-objective parametric optimization of nano powder mixed electrical discharge machining of AlSiCp using response surface methodology and particle swarm optimization has done. The use of powders enhances the machining characteristics of the EDM processes. Low voltage current (LVC), high voltage current (HVC), pulse-on time (Ton), pulse-off time (Toff) and flushing pressure (FP) are the input variables on which certain machining parameters such as material removal rate (MRR), surface roughness (Ra) and tool wear rate (TWR) are analyzed. A copper electrode of 99.98% purity with a diameter of 12 mm was used to cut AlSiCp12% metal matrix composite (MMC) in EDM.It is evident from the results that the powders enhance the machining rate and surface finish.The use of Nano particles shows significant variation in surface finish and material removal rate. It means MRR increases and surface roughness decreases.

S. Tripathy, D.K. Tripathyet.al [4] (2015),usedTOPSIS and grey relational analysis to study the multi-attribute optimization of machining process parameters in powder mixed electro-discharge machining. From the experimental results, it is observed that the roughness of the surface varies within a range of 3.8μm to 9.2μm when no powder is added to the dielectric fluid. When 3 gm/l of Cr powder is added, the roughness values are reduced to a range of 2.86μm to 5.97μm. On increasing the concentration of Cr powder to 6gm/l, the roughness further gets reduced to arrange for 2.4μm to 5.04μm. Thus, adding powder particles in proper size and concentration reduces the surface roughness during machining. From the examination of the photomicrographs, it is found that adding the conductive powder to the dielectric fluid improves the surface topography with fewer defects, cracks and surface roughness, which is directly related to the size of the crater formed and the distribution of recast layer on the surface.

Ahmed Al-Khazraji , Samir Ali Aminet.al [5] (2016), studied the effect of powder mixing electrical discharge machining (PMEDM) parameters using copper and graphite electrodes on the white layer thickness (WLT), the total heat flux generated and the fatigue life.The total heat flux values were increased with the increasing of pulse current values up to 22 A and the decreasing of a pulse on duration time to 40 µs. The graphite electrodes gave a total heat flux higher than copper electrodes by 82.4%, while using the SiC powder and graphite electrodes gave a higher total heat flux than copper electrodes by 91.5%, and by 285.3% and 602.7% more than using the copper and graphite electrodes and the kerosene dielectric alone, respectively. The lowest WLT values of 5.0 µm and 5.57 µm were reached at a high current and low current with a low pulse on time using the copper and graphite electrodes and the SiC powder, respectively. This means that there is an improvement by 134% and 67% when compared with using the copper and graphite electrodes and kerosene dielectric alone, respectively. The use of graphite electrodes with SiC powder gave fatigue stresses at 106 cycles as 275 MPa, which is higher by 7.00% when compared with the use of copper electrodes, and yielded a higher fatigue life than when working without mixing powder by 14.58% and 18.54% using the copper and graphite electrodes, respectively.

H.K. Kansal, Sehijpal Singhet.al [6] (2015), used finite element method to conduct a numerical simulation of powder mixed electric discharge machining (PMEDM).In the present paper, an axisymmetric two-dimensional model for powder mixed electric discharge machining (PMEDM) has been developed using the finite element method (FEM). The model utilizes the several important aspects such as temperature sensitive material properties, shape and size of heat source (Gaussian heat distribution), percentage distribution of heat among tool, workpiece and dielectric fluid, pulse on/off time, material ejection efficiency and phase change (enthalpy) etc. to predict the thermal behavior and material removal mechanism in PMEDM process. The simulation results show that the PMEDM produces smaller and shallower craters than EDM under the same set of machining conditions.

Vijaykumar S. Jatti, ShivrajBaganeet.al [7] (2017), conducted a thermo-electric modelling, simulation and experimental validation of powder mixed electric discharge machining (PMEDM) of BeCu alloys. Present study focuses on developing Finite Element model of Powder Mixed Electric Discharge Machining of Beryllium copper alloy with experimental validation.The workpiece material used for the study was beryllium copperalloy and electrolytic copper of high thermal conductivity was used as tool electrode. Aluminum oxide was used as powder in dielectric with particle mesh size of 150 mm. Experiments were conducted on Electronic make die sinking electric discharge machine. The numerical analyses were performed using a hexahedral second order element with 20 nodes and global mesh size of 0.75 mm. Approximately 28,400 elements and 1,65,000 nodes have been generated on the instance. The maximum temperature obtained in the simulation is higher than the boiling temperature of the material which means that the heat supplied is sufficient to melt the material. Thereby material removal takes place. It is also observed that as gap current increases the supplied heat increases and in turn increases the volume of material removal.. Most of the heat is taken away by the dielectric fluid through convection and some part of heat is taken away by molten metal.

GangadharuduTalla, SoumyaGangopadhyayet.al [10] (2014),used Grey Relation Analysisto study multi response optimization of powder mixed Electric Discharge Machining of Aluminum/Alumina Metal Matrix Composite.In this work, Aluminum/Alumina metal matrix composite (MMC) was fabricated and machined in EDM by mixing the aluminum powder in kerosene dielectric. The effect of process parameters (powder concentration, peak current, pulse on time and duty cycle) on two responses namely, material removal rate (MRR) and surface roughness (SR) were measured. The addition of Al powder particles in the dielectric has increased the MRR and decreased the SR in the EDM of Al/Al_2O_3 MMR. The maximum MRR (41.291 mm^3/min) was observed at a powder concentration of 4g/L. For the single response SR, the minimum value (7.524 µm) was found at 6 g/L concentration

3. POWDER PARAMETERS

We can take different types of parameters such as the concentration of powder, types of powder and abrasive size etc. In powder mixed electric discharge machining (PMEDM) to avoid the wastage of kerosene oil, a small dielectric circulating system is designed. A stirring system is incorporated to avoid the particle settling. The modified circulation and stirring system are designed in such a way that, it can be employed at the commercial level. In this system, a micro pump is installed for better circulation of the powder mixed dielectric fluid. The pump and the stirrer are employed in the same tank in which machining is performed. For constant reuse of powder mixed dielectric fluid, magnetic forces are used to separate the powder particles from the debris produced due to machining. PMEDM has a different machining mechanism from the conventional EDM. In this process, a suitable material in the powder form is mixed into the dielectric fluid of EDM.

4. MATERIAL SELECTION

Categories: Metal, Ferrous Metal, Tool Steel, Cold Work Steel, Oil-Hardening Steel

Material Notes: General purpose non-deforming low alloy for applications requiring extreme dimensional accuracy. Good

Keywords: UNS T31501, ASTM A681, FED QQ-T-570, SAE J437, SAE J438, DIN 1.2510

Table 1: Chemical Composition

Cu	Mn	Si	Zn	Fe	Cr
0.10	0.10	0.2	0.10	0.35	0.10

Tool Selection:

EDM electrodes consist of highly conductive and/or arc erosion-resistant materials such as graphite or copper. EDM is an acronym for electrical discharge machining, a process that uses a controlled electrical spark to erode metal. EDM electrodes include components made from brass, copper and copper alloys, graphite, molybdenum, silver, and tungsten. Electrical discharge machining (EDM) makes it possible to work with metal for which traditional machining techniques are ineffective. It only works (except by specific design) with materials that are electrically conductive. Using recurring electric discharge, it is possible to cut small, odd-shaped angles and detailed contours or cavities in hardened steel as well as exotic metals such as titanium and carbide.

Copper and copper alloys:

For better EDM wear resistance than brass, but are more difficult to machine than either brass or graphite. It is also more expensive than graphite. Copper is, however, a common base material because it is highly conductive and strong. It is useful in the EDM machining of tungsten carbide, or in applications requiring a fine finish.

Experimental Setup:

The detailed Machine specification is listed as follows:

Maximum work height: 175 mm

Main table traverse (X, Y): 280, 200 mm

Electrode diameter range: 0.25 mm to 15 mm

Interpolation: Linear and circular.

Tool material: Copper electrode.

The time of machining was recorded in minutes along with initial and final weights of the work piece were taken. The machining cycle was repeated for the next value of discharge current. The Material removal rate is calculated using the formula

$$\text{MRR} = \frac{\text{Initial weight} - \text{Final weight (gm)}}{\text{Machining time (min)}}$$

Surface roughness readings were taken on the bottom surface of the machined cavity. Surface roughness was measured by Surf test equipment giving Ra value in microns.

Fig. 2: General Experimental Setup

5. ANALYSIS OF RESULTS

Basically, experimental design methods were developed original fiche. However experimental design methods are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases, to solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only.

Table 2: Experimental Data after machining in PEDM

S.NO	PULSE ON TIME (sec)	PULSE OFF TIME (sec)	CURRENT (amps)	WORKPIECE BEFORE MACHINING (gms)	WORKPIECE AFTER MACHINING (gms)	TOOL BEFORE MACHINING (gms)	TOOL AFTER MACHINING (gms)	MACHINING TIME (sec)	MRR (mm³/s)	TWR (mm³/s)
1	500	40	5	122.72	121.79	59.96	59.92	12.38	0.001252	0.1938
2	500	40	6	121.79	120.93	59.92	59.89	8.68	0.001651	0.2073
3	500	40	7	120.93	119.99	59.89	59.86	6.97	0.002247	0.2582
4	500	50	5	119.99	119.12	59.86	59.83	11.87	0.001221	0.1516
5	500	50	6	119.12	118.24	59.83	59.79	9.38	0.001564	0.2558
6	500	50	7	118.24	117.31	59.79	59.75	8.19	0.001893	0.2930
7	500	60	5	123.68	122.73	59.75	59.72	10.46	0.001727	0.1720
8	500	60	6	122.73	121.78	59.72	59.69	9.17	0.002120	0.1962
9	500	60	7	121.78	120.84	59.69	59.65	7.39	0.001671	0.3247
10	600	40	5	120.84	119.62	59.65	59.62	12.17	0.001553	0.1479
11	600	40	6	119.62	118.84	59.62	59.58	8.37	0.001478	0.2867
12	600	40	7	118.84	117.22	59.58	59.54	6.03	0.001256	0.3980
13	600	50	5	125.00	124.03	59.54	59.51	12.87	0.001982	0.1398
14	600	50	6	124.03	123.03	59.51	59.48	8.41	0.002346	0.2140
15	600	50	7	123.03	122.16	59.48	59.44	6.18	0.001779	0.3883
16	600	60	5	122.16	121.08	59.44	59.40	10.12	0.001894	0.2371
17	600	60	6	121.08	120.24	59.40	59.37	7.39	0.002738	0.2435
18	600	60	7	120.24	119.21	59.37	59.34	6.27	0.001508	0.2870
19	700	40	5	123.08	122.16	59.34	59.31	10.17	0.001433	0.1769
20	700	40	6	122.16	121.43	59.31	59.29	8.49	0.002643	0.1413
21	700	40	7	121.43	120.45	59.29	59.26	6.18	0.001692	0.2912
22	700	50	5	120.45	119.43	59.26	59.22	10.05	0.001784	0.2388
23	700	50	6	119.43	118.53	59.22	59.19	8.41	0.002592	0.2140
24	700	50	7	118.53	117.60	59.19	59.15	5.98	0.001695	0.4013
25	700	60	5	124.26	123.24	59.15	59.11	10.03	0.001687	0.2392
26	700	60	6	123.24	122.31	59.11	59.08	9.19	0.002344	0.1958
27	700	60	7	122.31	121.41	59.08	59.04	6.40	0.001358	0.3750

Figure 4 shows that the maximum surface roughness was encountered at Maximum Pulse ON time and minimum Pulse OFF time. The Minimum was achieved at Maximum Pulse OFF time and Minimum Pulse ON time.

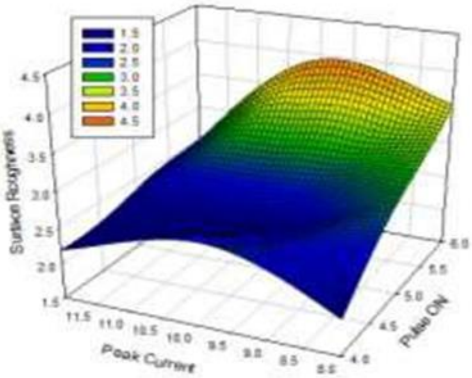

Fig. 4: Effect of Pulse ON and Peak current on Surface Roughness

The Minimum surface roughness was identified at Minimum Peak Current and Minimum Pulse ON time. The highest Surface roughness was recorded at Maximum Pulse ON time and at mid-range of Peak current. It deduces that the Minimum surface roughness was identified at Minimum Peak Current and Minimum Pulse OFF time. The highest Surface roughness was recorded at higher Pulse OFF time and at mid-range of Peak current.

Fig. 5: Effect of Pulse OFF and Peak current on Surface Roughness

Figure 6 shows that the maximum MRR was recorded at Maximum Peak current and Maximum Pulse OFF time. The lowest MRR was recorded at minimum Peak current and maximum Pulse OFF time. Figure 7 shows that the Maximum MRR is encountered at Maximum Peak Current and Minimum Pulse ON time. The Minimum MRR is encountered at Mid-range of Pulse ON and minimum of Peak current.

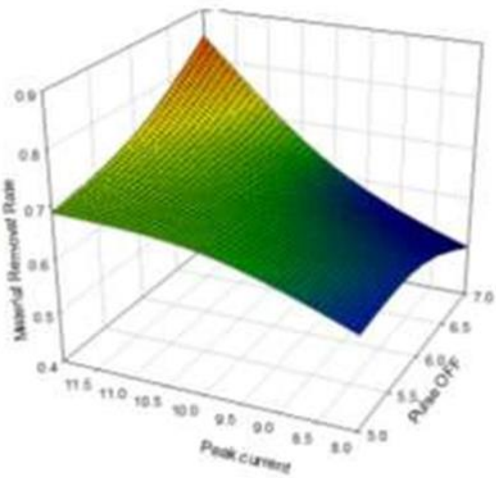

Fig. 6: Effect of Pulse OFF and Peak current on MRR

The most influential parameter that affects the Surface Roughness was found to be Pulse ON time whereas, for Material removal rate, Peak current was the most significant machining parameter.

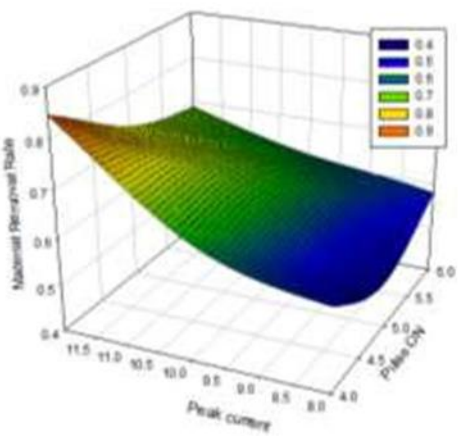

Fig. 7: Effect of Pulse ON and Peak current on MRR

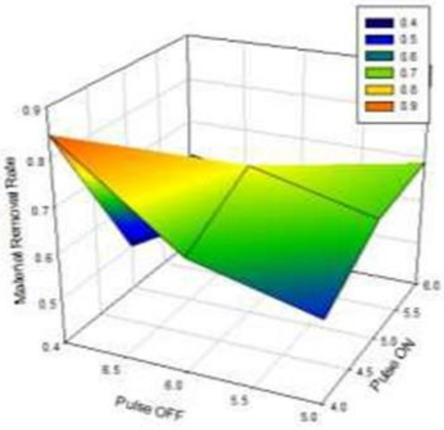

Fig. 8: Effect of Pulse ON time and Pulse OFF time on MRR

It indicates that the maximum MRR was encountered at least Pulse ON time and Pulse OFF time. A minimum was recorded at maximum Pulse OFF time and minimum Pulse ON time.

The predicted values of the Surface roughness and Material Removal Rate is compared with the actual value obtained in the experiment is shown in Figure 11 & 12. The predicted values are very close to the actual values.

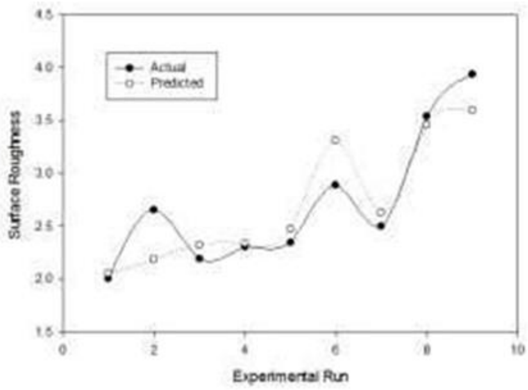

Fig. 9: Actual vs Predicted Surface Roughness

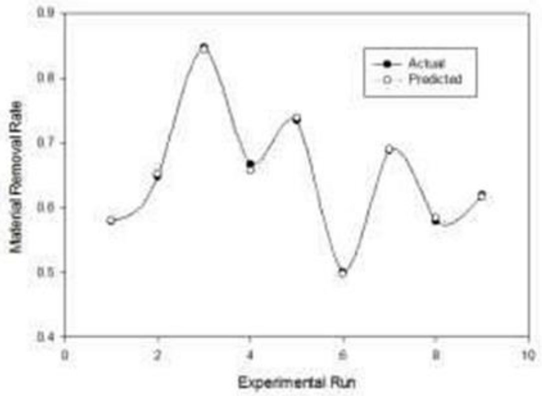

Fig. 10: Actual vs Predicted Material Removal Rate

6. CONCLUSION

- The experiments were carried out by adopting taguchi technique and the parameters were optimized.
- The most feasible parameter for SR is 6 seconds of Pulse ON time, 6 amps of Pulse OFF time and 10 amps of current.
- The most feasible parameter for MRR is 5 seconds of Pulse ON time, amps of Pulse OFF time and 8 amps of current.
- Response surface methodology was used to study the interaction effects.
- The most contributing parameter for Material Removal Rate was found to be Peak current.
- The most influencing parameter was found to be Pulse ON time for Surface Roughness.

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