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# Effect of Silicon Carbide Powder Mixed EDM on Machining Characteristics of SS 316L Material

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**ABSTRACT**: In this paper Silicon Carbide powders mixing into the dielectric fluid of EDM on machining characteristic of SS316 L materials has been proposed. Various process parameters namely peak current, pulse-on time, pulse-off time, powder concentration, powder grain size and nozzle flushing, duty factor, etc have been considered. The process performance is measured in terms of Response variables like Material Removal Rate(MRR) & Surface Roughness(SR). Number of experiments to be conducted is based on Taguchi orthogonal array with three level and three factors. The outcomes are expected to increase MRR, improve surface finish/reduce surface roughness.
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**KEYWORDS**: EDM, PMEDM, MRR, SR, Taguchi Method, ANOVA.

## I. INTRODUCTION

Electrical discharge machining (EDM) is one of the extensively used nonconventional material removal processes. It can be successfully employed to machine electrically conductive parts regardless of their hardness and toughness. In spite of remarkable process capabilities, limitations such as low volumetric material removal and poor surface quality are associated with EDM. In the recent past, powder mixed EDM (PMEDM) has emerged as one of the advanced techniques in the direction of the enhancement of the capabilities of EDM . In this process, a suitable material in fine powder form (aluminum, chromium, graphite, copper, or silicon carbide, etc.) is mixed into the dielectric fluid of EDM. The spark gap is filled up with additive particles. The added powder significantly affects the performance of EDM process. The electrically conductive powder reduces the insulating strength of the dielectric fluid and increases the spark gap distance between the tool electrode and workpiece. As a result, the process becomes more stable, thereby improving machining rate (MR) and surface finish. Powder Mixed EDM is a recent innovation of EDM for enhancing its capabilities.

## II. MATERIALS AND METHODS

The principle of PMEDM is shown in Figure 1. In this process, the material in powder form is mixed into the dielectric fluid either in the same tank or in a separate tank. When a voltage of 80-320 V is applied to both the electrodes, an electric field in the range 105 to 107 V/m is created. The spark gap is filled up with additive particles, and the gap distance between tool and the workpiece increases from 25 μm to 50 μm to many times larger (Figure 1). The powder particles get energized and behave in a zig-zag fashion. The grains come close to each other under the sparking area and gather in clusters. Under the influence of electric forces, the powder particles arrange themselves in the form of *chains* at different places under the sparking area (refer to Figure 1). 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 decreases. The easy short-circuit takes place, which causes early explosion in the gap. As a result, the '*series discharge*' 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 erosion from the workpiece surface. At the same time, the added powder modifies the plasma channel. The The electric density decreases; hence, sparking is uniformly distributed among the

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powder particles. As a result, even and more uniform distribution of the discharge takes place, which causes uniform erosion (shallow craters) on the workpiece. This results in improvement in surface finish.

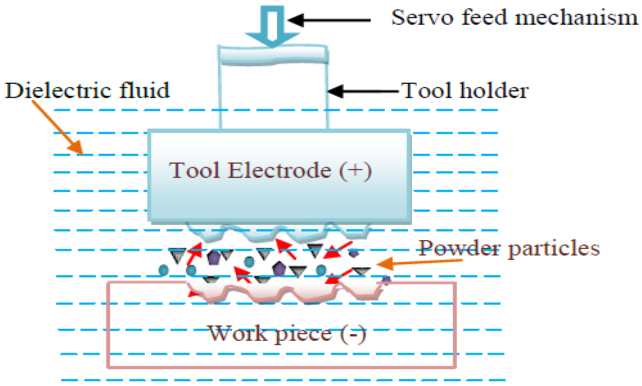


Figure 1: Principle of PMEDM Process

## III. LITERATURE REVIEW

**Kansal *et al.* [1]** studied the effect of silicon powder mixing into the dielectric fluid of EDM on machining characteristics of AISI D2 die steel. Peak current and concentration of powder were found to be most significant parameters for material removal. High MRR was achieved at high concentration of 4 g/l and large Peak current of 10 A.
**M. A. Razak, A. M. Abdul-Rani, and A. M. Nanimina [2]** investigated on SiC PMEDM powder concentration and powder particles size in cutting Stavax material(Hot Die Steel). The results are expected to increase MRR, improve surface finish, reduce TWR, reduce machining time and reduce machining cost.
**Pecas and Henriques [3]** studied that the addition of powder particles in suspension in the dielectric .The results showed the positive influence of the silicon powder in the reduction of the operating time, required to achieve a specific surface quality, and in the decrease of the surface roughness, allowing the generation of mirror-like surfaces. In this study Surface texture obtained for an electrode area of 32cm2 with and without silicon powder and for electrode area of 64cm2 with and without silicon powder. Results achieved with Silicon powder is 0.24µm and without silicon powder is 0.91µm.
**Kansal et al. [4]** they noted that by suspending silicon powder into the dielectric fluid of EDM and an enhanced rate of material removal and surface finish can be achieved. The material removal rate increases with the increase in the concentration of the silicon powder. The surface roughness decreases with the increase in the concentration of the silicon powder. The combination of high peak current and high concentration yields more MRR and smaller SR.
**Mahammadumar M. Jamadar, M.V. Kavade[5]** studied the effect of Aluminium Powder Mixed EDM on machining characteristics of Die Steel(AISI D3). The experimental results shows that Maximum MRR is obtained at a high peak current of 14Amp, higher Ton of 150µs, and high concentration of Al powder 6g/l, Low TWR is achieved with low peak current of 2Amp, lower Ton of 50µs and higher concentration of Al powder of 6 g/l and Low surface roughness is achieved with a low peak current of 2Amp, a higher Ton of 150 µs and higher concentration of Al powder of 6g/l.
**Rajendra.M, G. Krishna Mohana Rao[6]** analysed that Al2O3 abrasive particle size, concentration and pulse current are most significant parameters that improve MRR in comparison with traditional EDM. AISI D3 Die Steel was selected as work material. The results shows that MRR increases with increase in the concentration of the Al2O3 abrasive, at 6g/lit of concentration in the dielectric fluid, MRR is maximum. The MRR decreases with increase of abrasive particles concentration after certain limit. The abrasive mixed EDM results in 58% more MRR than the traditional EDM.
**Mohd. Junaid Mir, Khalid Sheikh, Balbir Singh and Navdeep Malhotra[7]** carried out parametric optimization of Surface Roughness (SR) study on the powder mixed electrical discharge machining (PMEDM) of H11 steel. Response surface methodology (RSM) has been used for developing, improving and optimizing the experiments. Central composite experimental design was used to estimate the model coefficients of the process parameters. Pulse time on,

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discharge current and concentration of Aluminum powder added into dielectric fluid of EDM were chosen as process parameters to study the PMEDM performance. Experiments have been performed on newly designed experimental setup and the analysis of variance revealed that the factors peak current and concentration are most influential parameters affecting SR.

**Ojha et al. [8]** experimentally investigated MRR and EWR in PMEDM process with Chromium powder suspended dielectric. It was concluded that MRR showed an increasing trend for increase in powder concentration. Work piece was selected as EN8.

**Ved Prakash and Deepak Kumar [9]** studied the effect of powder mixed dielectric on tool wear rate(TWR) . Experiments were designed using Taguchi method and appropriate Orthogonal Array and experiments have been performed as per the set of experiments designed in the orthogonal array. Signal to Noise ratios are also calculated to analyze the effect of PMEDM more accurately. Two powders are suspended in Dielectric one by one; namely graphite and copper. Workpiece selected was EN-31 die steel and electrode selected was copper.

**Zakaria Mohd Zain1, Mohammed Baba Ndaliman1, Ahsan Ali Khan1 and Mohammad Yeakub Ali1 [10]** conducted experiments with the outputs as MRR, SR and Micro –hardness. the discharge current was varied between 2.5 and 6.5 A, while powder concentration ranges between 5.0 and 15.0 g/l. Results indicate that the highest MRR of 0.38 g/min was obtained with TaC concentration of 15 g/l at the current of 6.5 A. TaC powder addition does not affect both the MRR and Ra at lower current. However, the level of micro-hardness attained was influenced by TaC powder concentration in dielectric fluid, the highest being 1,040 Hv with 5.0 g/l at the current of 2.5 A. Workpiece selected was SS304.

**Jai Hindus.S, Prasanna Rajendra Kumar.R, Oppiliyappan.B & P.Kuppan[11]** performed experiments as per the Box Behniken design on SS316L work piece. The results indicate that MRR,TWR is strongly influenced by current(A) and Pulse on time (Ton).

**Shriram Y. Kaldhone and M.V. Kavade[12]** carried out study on the influence of the parameters such peak current, Duty factor, pulse on time , work piece material, powder type , powder concentration and flushing pressure. Taguchi methodology has been adopted to plan and analyze the experimental results. Experiments have been performed on newly designed experimental setup. In this study seven factors with three levels are investigated using Orthogonal Array (OA) L27.Material removal rate (MRR) in this experiment was calculated by using mathematical method. The result of the experiment then was collected and analyzed using MINITAB 16 software. The recommended best parametric settings have been verified by conducting confirmation experiments for MRR. From the experimental study it is found that addition of Silicon carbide powder enhances machining rate drastically with slightly increase in Tool wear rate. Workpiece selected was Tungsten Carbide.

**Satpal Singh and C.S. Kalra[13]** carried out an experimental study of the machining performance of PMEDM on EN 24 alloy steel in terms of Material Removal Rate. A fine powder of tungsten has been suspended in the EDM oil dielectric as an additive. Experiments have been designed using Taguchi method. Taguchi L9 orthogonal array has been selected for 4-factors 3-levels design. The most significant factors contributing towards MRR and TWR have been identified. The results clearly showed that addition of tungsten powder has increased the MRR.

**Nimo Singh Khundrakpam, Som Kumar, Amandeep Singh, Gurinder Singh Brar[14]** has mixed Zinc powder with kerosene dielectric of PMEDM and experiment was conducted on EN8 steel. It is observed that significant factors for MRR are powder concentration, peak current and interaction of both. The parameters pulse off time and tool electrode diameter have no significant on the material removal rate.

## III. SCOPE OF RESEARCH

Based on the literature review carried out, it is observed that, the research on SS316L material using PMEDM is not yet explored. As we know the stainless steel material SS316L is very difficult to machining due to reasons such as having low thermal conductivity, high built up edge tendency and high corrosive resistance. Application of these materials is in various valve manufacturing industries, biomedical industries, pump industries & manufacturing of various product prototypes, etc. This is a research gap. As per the literature review carried out, it is observed that Silicon Carbide gives better result than other powders. Hence SiC is selected as powder material. Copper is selected as tool electrode as copper is high electrical conductive material. Kerosene is used as dielectric as it is the first popular dielectric oil. Its primary advantage is that it has very low viscosity and flushes very well. By using Silicon carbide (SiC) powder mixed

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in Dielectric of Kerosene, the experimentation work is to be performed to know the performance of PMEDM for SS316L material. The objectives of these research work are :

i) To study the effect of various input parameters i.e pulse on time, current on Material Removal Rate (MRR) and Surface Roughness (SR)

ii) To study the effect of various concentrations of SiC powder on Material Removal Rate (MRR) and Surface Roughness (SR)

## IV. PROPOSED METHODOLOGY

In this process, experiments are to be carried out electrical discharge machine. The tool electrode is copper cylinder of 25mm in diameter. In the present study experiments proposed to carried out on the dielectric flow system which was modified for circulation of Silicon Carbide (SiC) powder suspended dielectric medium in small quantities to prevent contamination of whole of dielectric fluid. SS316L was selected as work piece. Based on literature survey and preliminary investigations, the parameters chosen as inputs are Pulse-on time, peak current, and concentration of SiC powder. Nine experiments will be conducted with three factors and three level factorial design of experiment as shown in Table I and Table II. The MRR will be calculated by formula & Surface roughness is measured with surface roughness tester:

$$MRR= (Wb - Wa)/Tm$$

whereas Wb is the weight of the workpiece before machining; Wa is the weight of the workpiece after machining; and tm is the machining time.

Table I: Machining Parameters & their Level

| Machining Parameter | Symbol | Unit | Levels | | |
|---|---|---|---|---|---|
| | | | Level 1 | Level 2 | Level 3 |
| Pulse on time | Ton | μs | 50 | 100 | 150 |
| Discharge Current | Ip | A | 4 | 6 | 8 |
| Powder Concentration | P.C | g/l | 0 | 5 | 10 |

Table II: Taguchi Orthogonal Array Design For SiC Powder Mixed EDM

| Experiment | Factors | | |
|---|---|---|---|
| | Pulse On Time(Ton) | Current(A) | Powder Concentration(g/l) |
| 1 | 50 | 4 | 0 |
| 2 | 50 | 6 | 5 |
| 3 | 50 | 8 | 10 |
| 4 | 100 | 4 | 5 |
| 5 | 100 | 6 | 10 |
| 6 | 100 | 8 | 0 |
| 7 | 150 | 4 | 10 |
| 8 | 150 | 6 | 0 |
| 9 | 150 | 8 | 5 |

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## VI. EXPERIMENTATION & DATA ANALYSIS

The data to be collected from the experiments will be analyzed based on Taguchi method to find the effect of Pulse on time, Current & Powder concentration on MRR & SR. As the experimental design is orthogonal, it is possible to separate out the effect of each parameter at different levels. The analysis and graphical presentations are made using MINITAB. ANOVA is done to determine which parameter significantly affect on to the selected response variable.

## VII. CONCLUSION

Results achieved shall be compared with conventional EDM process data. Expected results are as follows:

i) High MRR using SiC Powder Mixed EDM as compared with conventional EDM process.
ii) Improve in Surface Finish/ reduction in Surface roughness using SiC Powder Mixed EDM as compared with conventional EDM process.

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