INFLUENCE OF ALUMINA NANO POWDER MIXED DIELECTRIC FLUID IN ELECTRIC SPARK MACHINING OF AISI D3 STEEL

A. SARAVANAKUMAR¹, K. SANTARAO² & G. NANDINI³

¹Professor, Department of Mechanical Engineering, GMR Institute of Technology, Rajam, Andhra Pradesh, India

²Assistant Professor, Department of Mechanical Engineering, GMR Institute of Technology, Rajam, Andhra Pradesh, India

³Research Scholar, Department of Mechanical Engineering, GMR Institute of Technology, Rajam, Andhra Pradesh, India

ABSTRACT

The aim of today's manufacturing world to produce high surface quality products. To achieve the desired output by through regulating the input process parameters as per the requirement. For that the current work, an experimental study is made on the effect of the pulse on time (Ton), discharge current, gap voltage and powder concentration of alumina nano - particle on surface roughness during machining of AISI D3 steel on electrical discharge machining (EDM). It is one of non-traditional machining operation in that cylindrical copper electrode with a diameter of 9.5 mm and a length of 240 mm was used as a tool electrode. Full factorial design of experiment method was employed by considering 4 factors and 2 levels. A total of 16 experiments was conducted with a possible combination of selected input factors. The results indicated that the additions of alumina nanoparticles in EDM oil are more influential on reducing the surface roughness.

KEYWORDS: Electrical Discharge Machining, Alumina & Surface Roughness

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INTRODUCTION

Electrical discharge machining (EDM) is one of the non-conventional machining processes. It is capable to machine hard materials and geometrically complex shapes which are not possible to machine in a normal conventional machining operation. Because of this special capability recent years EDM is extensively used in modern manufacturing field to produce complex jobs like molds and dies, which are very hard to manufacture by traditional machining [1]. This process works based on the principle of thermo-electric energy between tool and workpiece [2,3]. An electrical spark generated a small gap between the tool and work piece which causes removes the unnecessary material from the workpiece through melting and vaporization. The work piece (anode) and tool electrode (cathode) must be in conductive nature in order to produce spark [4]. In EDM there is no mechanical contact between the tool electrode and workpiece, since there is no risk of damage work material while doing a machining operation [5]. EDM finds much applications in current industries such as aircraft, aerospace, bio-medical and Nuclear [6].

Chern Lin et al. [7] conducted an experiment on Al-ZN-MG alloy with the addition of Sic powder into a dielectric fluid which reduces the surface roughness and also improved the wear resistance. Taxi and Chang [8] concluded that the addition of polymer powder in dielectric fluid for machining of stainless steel which causes the poor surface quality. B. Jabbaripour et al. [9] demonstrated experimentally over the effect of the pulse on time, open circuit voltage and pulse current over the surface roughness of Ti-6Al-4V alloy. They concluded that the pulse of time and pulse current more influence on surface roughness. M.K. Das et al. [10] also investigated over the effect of different

input parameters over the surface roughness and MRR in EDM by using WPCA approach. They found that the current followed by the voltage is more influence over multi-optimization of surface roughness and MRR. Kolli and Kumar [11] they mixed boron carbide nanoparticles into the dielectric for the machining of titanium alloys using EDM. By varying different concentrations of powder into the dielectric fluid and concluded that the addition of 15 g/l of boron carbide result gives the lowest surface roughness. Muthuramalingam et al.[12] in their research used Taguchi-grey relational analysis to optimize input parameters to minimize the surface roughness and maximize the MRR. They absorbed peak current most significantly influencing factor. The Different powder particles mixed into the EDM dielectric fluid which increases MRR and also reduces the surface roughness value compared to the normal EDM reported by Yeo et al [13], Chow et al [14] and Gunawan et al [15]. Powder concentration is the most important parameter which influence on the discharge process, it increases the gap distance between tool &work-piece and also the discharging rate. They found that best result was achieved for a powder concentration of 4 g/l within a range between 0.25 to 6 g/l. Decreasing the powder concentration leads to insufficient gap distance which is not able to support the discharge stability and increases the powder concentration higher the gap distance between the cathode and anode results insufficient discharge reported by Jeswani [16]. In the EDM process poor material removal rate and low surface quality observed at high-frequency spark (8000deg c -12000deg c) generated between tool and workpiece. To overcome this problem using Powder mixed electro-discharge machining (PMEDM) used in EDM which is a promising technique. It will improve the machining capabilities and also overcome the limitations of EDM. By adding fine conductive nanoparticles into the dielectric fluid will decreases the insulating strength and subsequently increases the distance between workpiece and electrode which makes easy removal of debris [17].

The current work is focuses on AISI D3 steel is one of the hardest materials and used in Blanking and forming dies, Forming roll, Press tools, Punches, Bushes etc. While doing machining with this type of materials in traditional way tool may get a chance to damage or internal stress may be induced on workpiece. To over comet, his problem electrical discharge machining (EDM) is selected to machine the AISI D3 steel. The main objective of this research work trying to reduce the surface roughness value through optimized the input process parameters.

MATERIALS AND METHODS

Work Materials

In this research paper, AISI D3 steel has taken work-piece material for conducting the experiment using EDM. Its hardness value 58-60 HRC, the prepared sample size was 30mm*30mm*5mm shown in Figure1. Chemical compositions and mechanical properties of the AISI D3 steel listed below Tables 1 and 2.

Table 1: Chemical Compositions of AISI D3 Steel

Carbon (C)	2-2.3
Manganese (Mn)	0.25-0.5
Sulfur (S)	0.056
Silicon (Si)	0.26
Phosphorous (P)	0.038
Chromium (Cr)	11-13
Molybdenum (Mo)	0.08
Iron (Fe)	Balance

Figure 1: AISI D3 Steel Work Piece

Table 2: Properties of AISI D3 Steel

Properties	Values
Thermal Conductivity (W/mK)	20
Density (g/cc)	7.67
Electrical resistivity (Ω /cm)	0.000072
Specific heat capacity (J/g°C)	0.5
Dimensions(mm)	30*30*5

Tool Material

In this paper cylindrical copper electrode with a diameter of 9.5mm and length of 240mm, was used as a tool because it has high thermal conductivity, density, higher melting point and easily machinable shown in Figure 2. Thermo - physical properties of electrode showed in Table 3.

Figure 2: Copper Electrode

Table 3: Thermo Physical Properties of Electrolytic Copper

Properties	Value
Thermal conductivity	401 kg/m ³
Density	8.96 g/cc
Melting point	1083 ° C
Electrical resistivity	0.00000171W/m-K

Dielectric Fluid

The Alumina (Al₂O₃) particle size 50nm is mixed with the commercial EDM oil by two-step method by taking two different concentration range 0.2 and 0.6wt%. XRD images confirmed that received nanoparticles are alumina particles which are shown in Figure 3. This Alumina powder is chosen in this study because it is chemically more stable and properties of the Al₂O₃ listed below table 4.

Figure 3: X-Ray Diffraction of Al_2O_3 nano Powder

Table 4: Properties of Al_2O_3 NANO Particles

Property	Value
Atomic weight	$101.96 \text{ g mol}^{-1}$
Average particle size	50nm
Melting point	2055°C
purity	99.99%
Density	3.97 g/cm^3
Color	White
Morphology	Spherical

DESIGN OF EXPERIMENT

Processes Parameters

There are many parameters available in the machining process, still, the main focus of every researcher is to reduce the surface roughness and increases the MRR in any kind of Machining processes. The current research work aims to reduce surface roughness, for these purposes the following input parameters are considered in this study: peak current, gap voltage, powder concentration, pulse on time. In this experimental study, all possible combinations of levels taken. The full factorial design method was adopted for optimizing input factors so that there are 2^n (where two indicates the number of levels, n represents a number of factors here 4 factors taken in this study $n=4$ i.e., $2^4=16$) trials in the experiment listed below table 5 and 6.

Table 5: Selected Machining Parameters and its Deviations

LEVELS	I	II
Discharge current (amps)	4	8
Gap voltage (Volts)	50	70
Powder concentration (g/lit)	0.2	0.6
Pulse on time (μ sec)	200	400

RESULTS AND DISCUSSIONS

Totally 16 experiments were conducted using full factorial design and a machined specimen is shown in Figure 4. The Surface roughness value measured using ZEISS SANDYSURF E-35B Mobile Surface Measuring Instrument at three different locations of each specimen and average of the observed values is given in Table 6. The present investigation results are analyzed with the help of Minitab 15 software.

Table 6: Experimental Results of Average Surface Roughness

St order	Run order	Ip	Vg	Pc	Ton	Ra
13	1	4	50	0.6	400	3.22
2	2	8	50	0.2	200	3.6
10	3	8	50	0.2	400	4.47
11	4	4	70	0.2	400	4.59
3	5	4	70	0.2	200	4.91
5	6	4	50	0.6	200	3.34
1	7	4	50	0.2	200	4.1
14	8	8	50	0.6	400	5.12
7	9	4	70	0.6	200	5.04
12	10	8	70	0.2	400	3.58
8	11	8	70	0.6	200	4.9
6	12	8	50	0.6	200	3.57
9	13	4	50	0.2	400	4.77
15	14	4	70	0.6	400	3.96
4	15	8	70	0.2	200	4.76
16	16	8	70	0.6	400	4.89

Figure 4: Machined Work Pieces

Figure 5: Factors Effect of Surface Roughness

Peak current, gap voltage, powder concentration, and pulse on time their level's effect on the formation of average surface roughness are shown in Figure 5. Addition of small amount alumina particles in a dielectric fluid drastically reduced the surface roughness value. When peak current varying from 4 to 8 Amps, it increases the surface roughness value. When the gap voltage increased from 50 to 70V, it also increases the surface roughness value. When increasing the powder concentration from 0.2 to 0.6g/lit it reduces the surface roughness value which is a favourable condition for improving the surface finish of the machined specimen. From above graph, it clearly indicates that the addition of powders into dielectric fluid reduced the surface roughness.

Using this Pareto chart and normal probability plot analysed the effects of different input parameters and its combination on the surface roughness of the machined specimen shown in Figure 6 and 7. It shows the magnitude and importance of the effect of various machining parameters. Pareto chart exhibits the complete values of the effects and also indicates the reference lines on the chart. If any parameter extends this line in the past is potentially important [18, 19].

Figure 6: Pareto Chart for Surface Roughness

Figure 7: Normal Probability Plot for Surface Roughness

In this chart combination of Peak current, powder concentration, and pulse on time (ACD) very close to the line and further it is observed that the powder concentration (c) exclusively influenced on the surface roughness of the EDM process. In Figure 7 Normal probability plot also shows the same results and the parameters ACD and C are placed far away from the starting line. The parameters which lie far away from the line are the most influencing parameter on the response of the process [19, 20, 21, 22]. Further, from the observation of the above two plots, it can be concluded that powder concentration is the most influencing factor compared to all other factors considered for this study.

CONCLUSIONS

In this experimental investigation are carried out using a Full factorial design of experiment concept and 16 tests were performed. Alumina powder particles mixed in the dielectric fluid used in this experiment and Copper electrode act as a tool electrode for machining of AISI D3 steel. The observed Surface roughness were analyzed and the following conclusions were drawn:

- Addition of alumina powder into the dielectric fluid increases the surface finish. Surface roughness value obtained at the concentration of 0.6 g/lit is less when compared to 0.2 g/lit.
- When compared to all other parameters, powder concentration reduces the surface roughness values when increased from low level to high level. But reaming all other parameters increased the surface roughness value

when increased from low level to high level.

- Finally, optimum surface roughness obtained in this study at Peak current (4 amp), gap voltage (50 v), powder concentration (0.6 g/lit) and pulse on time (200 μ sec).

REFERENCES

1. Gangil, M., & Pradhan, M. K. "Modeling and optimization of electrical discharge machining process using RSM: A review". *Materials Today: Proceedings*, 4(2), 2017, pp.1752-1761.
2. Kunieda, M., Bert Lauwers, K. P. Rajurkar, and B. M. Schumacher. "Advancing EDM through fundamental insight into the process." *CIRP Annals-Manufacturing Technology* 54, no. 2, pp.64-87, Jan.2005.
3. Abbas, NorlianaMohd, Darius G. Solomon, and MdFuadBahari. "A review on current research trends in electrical discharge machining (EDM)." *International Journal of machine tools and Manufacture* 47, no. 7-8, pp.1214-1228, Jun 2007.
4. Khanra, A. K., L. C. Pathak, and M. M. Godkhindi. "Application of new tool material for electrical discharge machining (EDM)." *Bulletin of Materials Science* 32, no. 4, pp.401-405, Aug 2009.
5. Dastagiri, M., and A. Hemantha Kumar. "Experimental Investigation of EDM Parameters on Stainless Steel&En41b." *Procedia Engineering* 97, pp.1551-1564, Jan 2014.
6. ShaliniMohanty, Ankan Mishra, B.K. Nanda, B.C. Routara, "Multi-objective parametric optimization of nano powder mixed electrical discharge machining of AlSiCp using response surface methodology and particle swarm optimization." *Alexandria Engineering Journal*, dx.doi.org/10.1016/j.aej.2017.02.006, 2017.
7. Lin, Yan Cherng, BiingHwa Yan, and Fuang Yuan Huang. "Surface modification of Al–Zn–Mg aluminum alloy using the combined process of EDM with USM." *Journal of Materials Processing Technology* 115, no. 3, pp.359-366, Sep 2001.
8. Tsai, Yao Yang, and Chih Kang Chang. "Effects of polymer particles suspending in dielectric fluid on surface roughness of EDM." In *Advanced Materials Research*, vol. 97, pp. 4146-4149. Trans Tech Publications, 2010.
9. Jabbaripour, B., et al. "Investigating the effects of EDM parameters on surface integrity, MRR and TWR in machining of Ti–6Al–4V." *Machining Science and Technology* 16.3, pp.419-444, Jul 2012.
10. Das, M. K., K. Kumar, T. K. Barman, and P. Sahoo. "Optimization of Surface Roughness and MRR using WPCA. Elsevier." *Science Direct* 64, pp. 446-455, 2013.
11. Kolli, Murahari, and Adepu Kumar. "Effect of boron carbide powder mixed into dielectric fluid on electrical discharge machining of titanium alloy." *Procedia Materials Science* 5, pp.1957-1965, Jan 2014.
12. Muthuramalingam, T., and B. Mohan. "Application of Taguchi-grey multi responses optimization on process parameters in electro erosion." *Measurement* 58, pp.495-502, Dec 2014.
13. Yeo, S. H., P. C. Tan, and W. Kurnia. "Effects of powder additives suspended in dielectric on crater characteristics for micro electrical discharge machining." *Journal of Micromechanics and Micro engineering* 17, no. 11, pp.91-98, Oct 2007.
14. Chow, Han-Ming, Lieh-Dai Yang, Ching-Tien Lin, and Yuan-Feng Chen. "The use of SiC powder in water as dielectric for micro-slit EDM machining." *Journal of materials processing technology* 195, no. 1-3, pp.160-170, Jan 2008.
15. Prihandana, GunawanSetia, Muslim Mahardika, M. Hamdi, Y. S. Wong, and Kimiyuki Mitsui. "Effect of micro-powder suspension and ultrasonic vibration of dielectric fluid in micro-EDM processes—Taguchi approach." *International Journal of Machine Tools and Manufacture* 49, no. 12-13, pp.1035-104, Oct 2009.

16. Jeswani, M. L. "Effect of the addition of graphite powder to kerosene used as the dielectric fluid in electrical discharge machining." *Wear* 70, no. 2, pp.133-139, Aug 1981
17. Tripathy, S., and D. K. Tripathy. "Multi-attribute optimization of machining process parameters in powder mixed electro-discharge machining using TOPSIS and grey relational analysis." *Engineering Science and Technology, an International Journal* 19, no, pp.62-70, Mar 2016.
18. L. Savadamuthu, S. Muthu, PVivekanandan, "Optimization of Cutting Parameters for turning Process using Genetic Algorithm." *Eur J Sci Res.* 69-1, pp.73-80, 2012.
19. A. Saravanakumar, P. Sasikumar, and S. Sivasankaran. "Effect of graphite particles in drilling of hybrid aluminum matrix composite." *Procedia Engineering* 97, pp. 495-504, 2014.
20. A. Saravanakumar, P. Sasikumar, and S. Sivasankaran, "Investigation of machinability of Graphite particle reinforced Al-MMC", *International Journal of Applied Engineering Research*, 10 (8), pp.6206-6209, 2015.
21. A. Saravanakumar and P. Sasikumar. "Assessment of factors influencing burr height on the machining of particle reinforced hybrid composites." *Journal of Material Environmental Science* 6, no. 5, 1638-1645, 2015.
22. Rao, S. Chiranjeeva, A. Saravanakumar, and G. Chandra Sekhar. "Influence of nano added MME blends on CI engine based on DOE concept." *International Journal of Mechanical Engineering and Technology*, Volume, 8, Issue 7:pp.860-868, 2017.