Effect of Silicon and Aluminum oxide Powder on MRR and Ra during machining of Ti-6Al-4V alloy using powder mixed electro-discharge machining

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Abstract : The use of Ti–6Al–4V is widened in the aerospace, automobile, and biomedical fields, but is challenging to a machine with conventional methods. Electrical discharge machining (EDM) is stared as one of the most operative methods to machining Ti–6Al–4V alloy, since it is a non-contact electro-thermal machining method, and it is sovereign from the mechanical properties of the processed material. In electro-discharge machining (EDM), dielectric plays an important role during the machining operation. The machining characteristics are greatly influenced by the nature of the dielectric used during EDM machining. In the current paper, dielectric as Al_20_3 powder suspended dielectric is used. Peak current, pulse on time, pulse off time and percentage of powders added into the dielectric fluid is chosen as process parameters to study the performance in terms of MRR and Ra. The experiments were carried out in planning mode on a specially designed experimental set up developed in a laboratory. Response surface methodology is employed to analyze the experiments.

IndexTerms - Ti–6Al–4V, PMEDM, Response surface methodology.

I. INTRODUCTION

The new idea of assembling utilizes non-regular vitality sources like sound, light, mechanical, and electrical. With the modern and mechanical development, advancement of harder and hard to machine materials, which find wide application in aviation, nuclear engineering and other industries owing to their high strength to weight ratio, hardness and heat resistance qualities has been witnessed. In this analysis Ti-6Al-4V alloy is been utilized as work-piece for examination. Ti-6Al-4V alloy has wide assortment of uses in aviation airframe, motor segment and furthermore major non-aviation applications in the marine, seaward and power age enterprises. In any case, Ti-6Al-4V super alloy is a hard to-cut material, displays poor machinability for the greater part of the regular machining forms, particularly amid the boring of holes and through openings. Thus, machining of titanium super alloy utilizing non-conventional machining procedures, for example, electro discharge machining (EDM) has been distinguished to be most proper machining method since there is no inclusion of mechanical powers amid machining [1-3]. Electrical Discharge Machining (EDM) is non-traditional, no physical cutting forces between the tool and the work piece, high precision metal removal process using thermal energy by generating a spark to erode the work piece. The work piece must be a conductive electricity material which is submerged into the dielectric fluid for better erosion. EDM machine has wide application in production of die cavity with large components, deep small diameter whole and various intricate holes and other precision part. Benefits of EDM: (a) it is a non-traditional process that generates no cutting forces, produces burr-free edges, permitting the production of small, fragile pieces. (b) An EDM machine allows the production of intricate parts and superior finishes with minimum operator intervention. (c) Since material removing by melting and evaporation in EDM, so there is no limitation of machining hard materials eliminating the deformation caused by heat treatment. (d) Machining of complex shapes, three dimensional micro work pieces. (e) Material that is electrically conductive can be cut and very accurate structures can be machined using the EDM process. Limitations of EDM: (a) Low material removal rates. (b) Lead time is needed to produce specific, consumable electrode shapes. (c) The work-piece has to be electrically conductive. (d) High specific energy consumption. (e) Thermal stresses are induced in the work-piece surface due to thermal shocks. Some investigations have been carried out to improve the electrical discharge machining (EDM) performance by modifying the EDM process without changing its working principle. The modification of the system includes powder mixed with dielectric EDM, dry EDM, ultrasonic EDM. This study focused on powder mixed dielectric EDM (PMEDM). PMEDM method involves the use of different types of powder such as silicon, nickel, titanium, manganese, tungsten, chromium etc. mixed with the dielectric during EDM process resulting in improvement of EDM performance [4, 5]. PMEDM is a technique for improvement of EDM performance. Mixing powder with dielectric during EDM process reduces dielectric strength creating early electric discharges, enlarges discharge gap, disperses discharge points evenly, and stabilizes discharge process thus improves EDM performance and machined surface properties [6, 7]. Rahman[8] has been reported on modelling, optimization and to develop of mathematical model of MRR for Ti-5Al-2.5Sn using RSM. The EDM was carried out on this material employing positive polarity of copper electrode. T On , V and T off was considered as input parameter to correlate with MRR. S. Assarzadeh [9], this paper present an effort to model and optimize the process parameters involved in powder-mixed electrical discharge machining (PMEDM). Aluminum oxide (Al_2O_3) fine abrasive powders with particle concentration and size of 2.5–2.8 g/L and 45–50 µm, respectively, were added into the kerosene dielectric liquid of a die-sinking electrical discharge machine. The CK45 heat-treated die steel and commercial copper was used as work piece and tool electrode materials, respectively. Based on the preliminary and screening tests as well as the working characteristics of selected EDM machine, discharge current (I), pulse-on time (Ton), and source voltage (V) were designated as the independent input variables to assess the process performance in terms of material removal rate (MRR) and surface roughness (Ra). G.Kumanan[10], Discusses the influence of processing parameters of electrical discharge machining (EDM) such as peak current, pulse on time, rotational speed and flushing pressure. This study also attempts to study the effects of parameters on EDM performance characteristics on Ti-6Al-4V alloy using copper electrode as tool material. The performance characteristics are analyzed in terms of material removal rate (MRR) and surface roughness (Ra), by varying the process parameters. Optimum machining parameter combinations are compared to the predicted values and the percentage of error was less than 2%. G. Kibria[11] had conducted experiment and analysis on Ti-6Al-4V super alloy employing deionized water based dielectric other than conventional hydro-carbon oil i.e. kerosene. with 4 gm./lit of boron carbide (B_4C) powder as additive in deionized water dielectric at different discharge energies and also with deionized water dielectric . EDM was employed to machine Ti-6Al-4V with Tungsten micro-tool, 300 µm diameters. Boron carbide (B_4C) mixed de-ionized water resulted higher material removal rate (MRR) compared to pure water for considered peak current and pulse-on-time parametric settings.

From above survey, Ti-6Al-4V super alloy has many wide variety of applications thus to machine this super alloy EDM process is employed. But, by doing survey came to know that use of powder mixed dielectric in EDM process give good results compare to simple EDM process. Further not much more research is being done on machining of Ti-6Al-4V material by PMEDM process Effort has been made to study the influence of process parameters on performance of various aspects of machining like; MRR, Ra.

II Experimental setup:

To investigate process parameter two set of experiments were performed. One set using silicon powder with and another with aluminum oxide. 30 experimental runs were conducted for each powder. The process parameter and their levels are shown in table 1. The experimental plans were designed on the basis of the central composite design (CCD) technique of RSM by using Design Expert Software (DOE).

Factors	units	Levels		
		-1	0	+1
Peak current	Amp	3	9	17
Pulse On Time	µsec	82	145	256
Pulse Off Time	µsec	55	110	183
Powder Concentration	gm./lit	0	2	4

In experiment, a small dielectric re-flowing framework was made-up and connected to the machine table. Business lamp fuel has been chosen as a dielectric liquid. A consideration was taken to with the end goal that the powder does not go into the fundamental dielectric tank, to guarantee that powder filtration is dodged. Tests are led on Ti-6Al-4V composite. Copper with 99% virtue is utilized as an apparatus anode.

For stirring up Silicon powder into lamp fuel dielectric, a little tank made of thin aroused particle sheet was set in the primary machining tank to isolate it from the sifting arrangement of the machine. A stirrer was utilized at the base of the pump to abstain from settling powder and to keep up even centralization of the powder in the dielectric all through the machining cycle. A similar procedure is finished utilizing another powder, aluminum oxide to finish another arrangement of the trial. The yield parameter chose for ponders are the MRR and Ra. Figures 1 (a) and (b) demonstrate the schematic representation diagram and the diagram of the real setup separately.

III. Results and Discussion

3.1 Effects on MRR

3.1.1 Effect of peak current on MRR: It is seen that from figure 2, in the two conditions i.e. with and without powders, the estimation of MRR is expanding with an increment in a top current The increase in MRR with increase in peak current is mainly due to more energy input in the process with rise in peak current. This extra energy will create deeper cavities which turn results in dislodging the work piece material at higher rates. Hence, MRR increases with increase in peak current for both the case i.e. for silicon containing dielectric fluid as well as aluminum oxide containing dielectric fluid. At 3 Ampere, the increase in MRR is observed to be nearly 65% and 58% for silicon containing dielectric fluid as well as aluminium oxide containing dielectric fluid respectively. At 9 Ampere, the increase in MRR is observed nearly 51% and 33% for both the cases respectively. And for 17 Ampere, the increase in MRR percentage is 38% and 34% for both cases respectively.

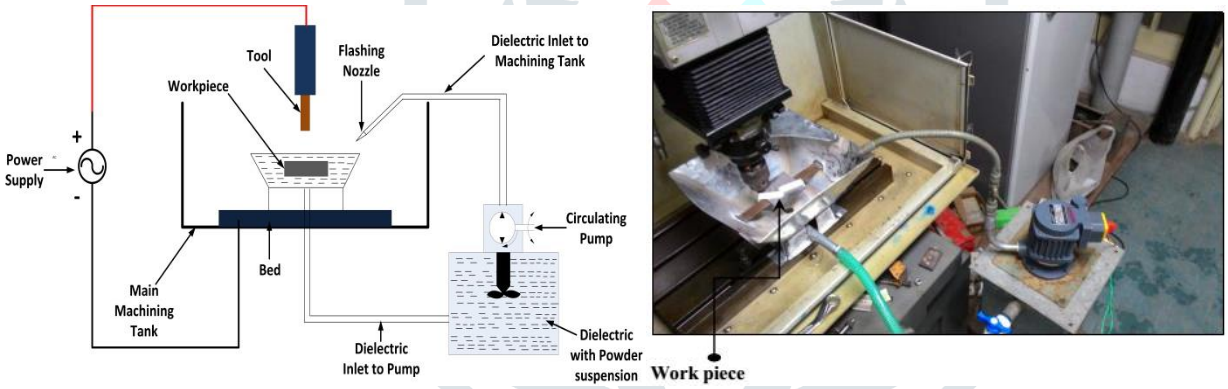

Figure 1. (a) Schematic Diagram Of experimental setup; (b) Experimental setup at a laboratory. [12]

3.1.2 Effect of Powder concentration on MRR: MRR enhances with the increase of concentration till 4gm/lit of powder concentration level. This is because the added additives cause a bridging effect between both electrodes, facilitates the dispersion of discharge into several increments and hence increases in MRR. It is observed that maximum MRR is obtained at 4gm/lit and MRR is found lower at 2gm/lit and follows same for 0gm/lit concentration level. At 2gm/lit, the increase in MRR is observed nearly the same for both the cases i.e. 77%. And for 4gm/lit, the increase in MRR percentage is 92% and 83% for both cases respectively.

3.1.3Effect of the pulse on time on MRR: From figure 3(a), it is clearly seen that there is an increase in MRR with the increase in pulse on time in exponential curve manner. From figure 3(b), with an increase in pulse on time there is a gradual increase in MRR. Excessive on-times can be counterproductive. When the optimum on-time for each electrode material/work metal combination is exceeded, the Metal Removal Rate (MRR) actually starts to decrease.

3.1.4 Effect of pulse off time on MRR: From figure 4(a) with the increase in pulse off time there is a gradual increase in MRR and from figure 4(b) gradually increasing powder concentration level and decreasing pulse off time level MRR increases. The cycle is done when sufficient off-time is allowed before the start of the accompanying cycle. Off-time will impact the rate and the quality of the cut. On a basic level, the shorter the off-time the speedier the machining operation will be; then again, if the off-time is too short, the shot work piece material won't be cleaned up by the surge of dielectric and the fluid won't be demonized.

3.2 Effect on Ra

3.2.1 Effect of peak current on Ra: It is observed that from figure 4, in both conditions the surface roughness becomes worse with an increase in peak current. This is attributable to the increase in discharge energy and impulsive force with increase in peak current; more melted material will be removed to produce deeper and large discharge craters. A large amount of crater, deep and long micro cracks on the work piece EDM with pure kerosene, which is responsible for the worst surface roughness data.

3.2.2 Effect of Powder concentration on Ra: Figure 5 reveals the effect of concentrations on surface roughness. It shows that at all levels of peak current the surface roughness value is increasing with increase in powder concentration. The concentration level of 0gm/lit and 2gm/lit is not the optimum concentration level for both the powders from the point of view of surface roughness. At this concentration levels, the gap distance does not increase enough so that the electrical discharge is distributed uniformly. The energy released from a single spark is not distributed evenly over the whole machining area. Hence, the surface roughness is getting worse for the above concentrations. When the concentration level increases more than 2m/lit, it results in the increase in spark gap and more uniform distribution of the discharge energy with the spark gap. The energy released from one singular spark distributed into many points due to bridging effect. Due to this process, the ions are bombarded on the work piece with the lower energy resulting in a shallow and large crater. This, in turn, results in reduced surface roughness. In absence of any powder additives, the increase in Ra is observed to be nearly 66% for silicon containing dielectric fluid as well as an aluminum oxide containing dielectric fluid. At 2gm/lit, the increase in Ra is observed nearly the same for both the cases i.e. 44%. And for 4gm/lit, the increase in Ra percentage is 68% and 57% for both cases respectively.

3.2.3 Effect of the pulse on time and pulse off time on Ra: From figure 6 and 7, Increase in pulse on Ra tends to decreases As we can say that increase in duty cycle with a gradual increase in powder concentration we get help in minimizing Ra. An increase in the level of powder concentration and keeping duty cycle between 55% -59% we get a lesser value of surface roughness.

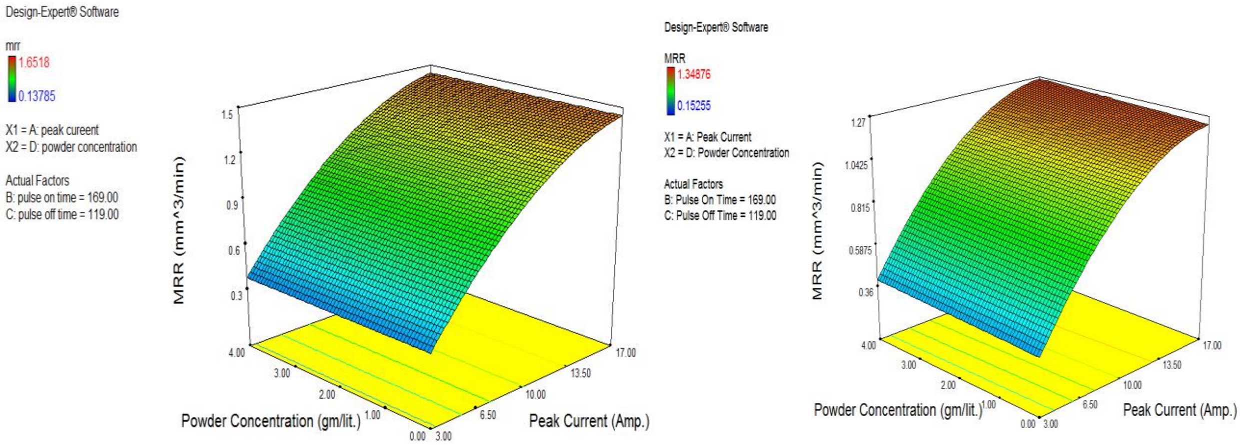

Figure 2. Response surface for MRR showing the effect of current and powder concentration for (a) silicon powder; (b) Aluminium oxide powder.

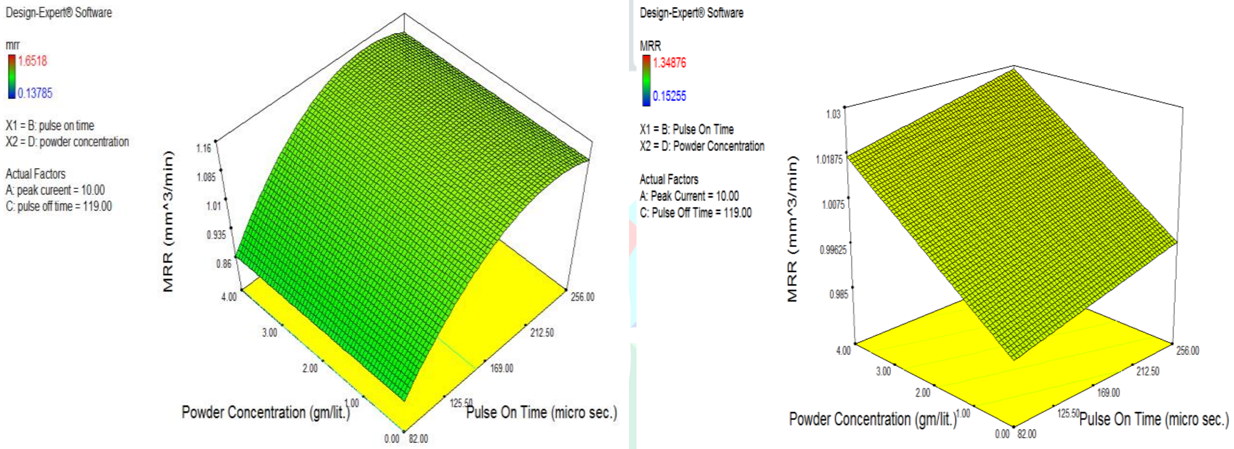

Figure 3. Response surface for MRR showing the effect of Pulse On time and powder concentration for (a) silicon powder; (b) Aluminium oxide powder

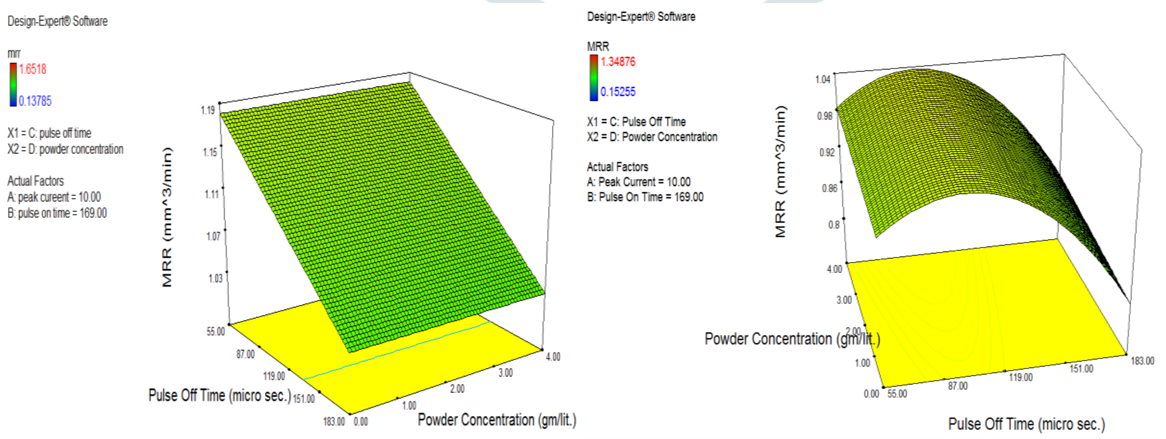

Figure 4. Response surface for MRR showing the effect of Pulse Off time and powder concentration for (a) silicon powder; (b) Aluminium oxide powder.

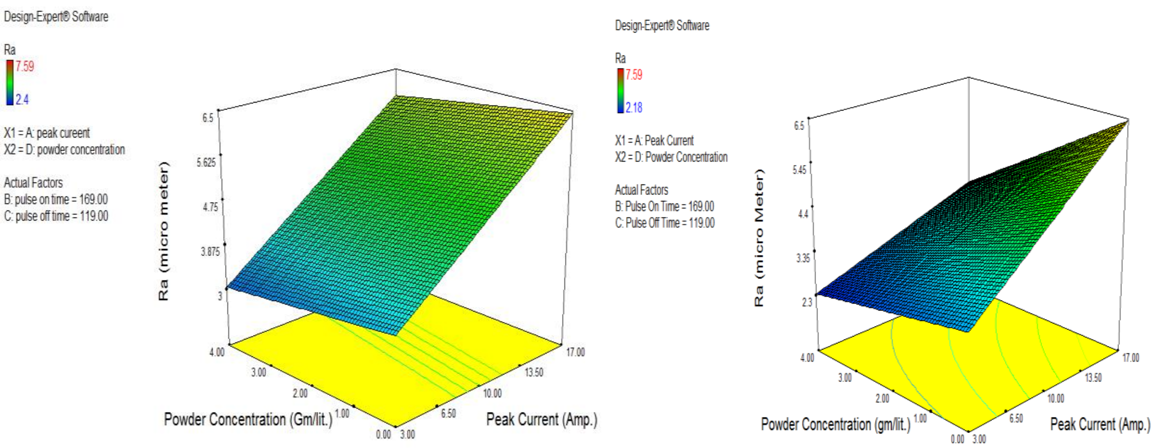

Figure 5. Response surface for Ra showing the effect of current and powder Concentration for (a) silicon powder; (b) Aluminium oxide powder.

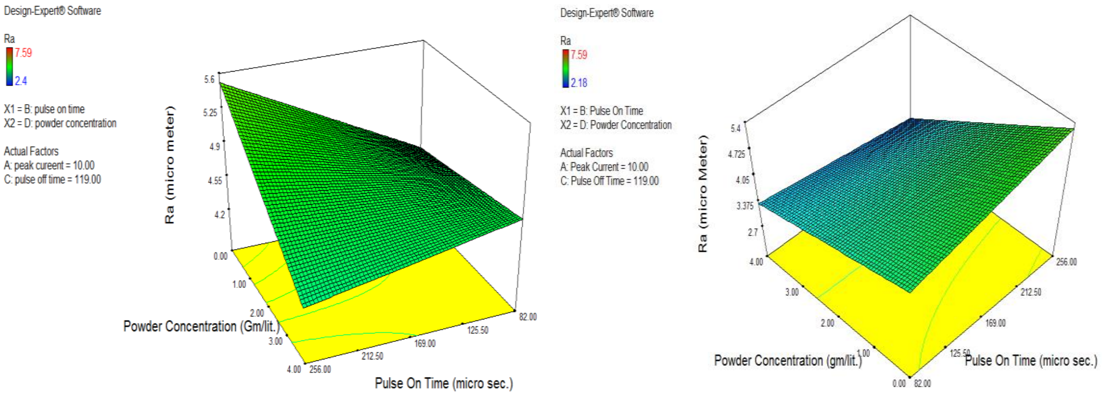

Figure 6. Response surface for Ra showing the effect of Pulse On time and powder concentration for (a) silicon powder; (b) Aluminium oxide powder.

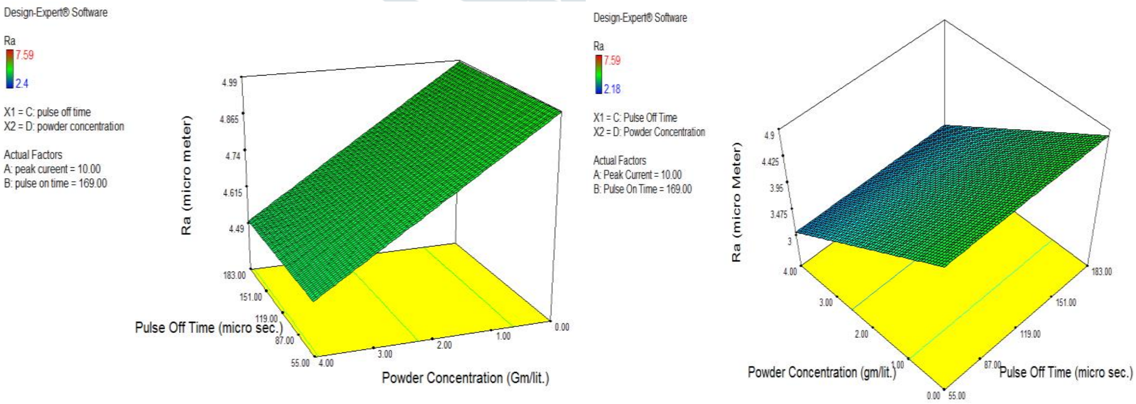

Figure 7. Response surface for Ra showing the effect of Pulse Off time and powder concentration for (a) silicon powder; (b) Aluminium oxide powder.

V. Conclusions

We can conclude that the percentage increase in MRR goes on decreasing with increase in peak current.We can conclude that the percentage increase in MRR goes on increasing with increase in powder concentration but at 2gm/lit concentration level the percentage increase in MRR is lower compared to 0gm/lit and 4gm/lit.We can conclude that the percentage increase in Ra is more for 0gm/lit and 4gm/lit and goes on increasing with increase in powder concentration but at 2gm/lit concentration level the percentage increase in Ra is lower compared to 0gm/lit and 4gm/lit.Peak current and powder concentration has a significant effect on responses in both the cases. Use silicon powder is more advisable to get high MRR but at loss of Surface Roughness. In case of aluminum oxide powder, we get the lesser value of MRR compare to silicon powder with the advantage of good surface finish. Most of the researches available on powder mixed dielectric employed macro size powders. There is a need for more investigations on the effect of Nanopowder since the smallest size of powder the better its suspension are. Application of EDM and PMEDM can be potential in biomedical implants machining but there is little documentation in literature. It will good to investigate more EDM and PMEDM application in biomedical implant manufacturing.

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