Electro Discharge Machining Parameters of Composite material: A Review

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Abstract

Electric discharge machining (EDM) is the type of non-conventional machining in which controlled metal-removal is done by means of electric spark erosion. In this process an electric spark is used as the cutting tool to cut (erode) the workpiece to produce the finished part to the desired shape. It us used for machining complex shapes accurately. On the other side the machining cost by Electro Discharge machining is comparatively high in comparison to other conventional matching processes. In this investigation, the input parameters such as Pulse on time, Pulse off time, Peak current and output parameters such as Metal removal rate (MRR), Surface roughness (SR), Tool or electrode wear ratio (TWR) are deeply focused in the past researchers and investigation. The objective of this paper to review the past researches and develop the way for advance Research.

Keywords: EDM, MRR, EWR, surface roughness.

1. Introduction

Electric Discharge machining (EDM) is on type of non- traditional machining process i.e. where there is no mechanical conduct between tool and work piece. EDM is also known as a spark erodes thermo- electric unconventional machining process [1]. In conventional machining process the machining of complex shape like aircraft engine industry the cost of machining is high and also the surface finish is not obtain value. [2]. EDM machine the work material by means of spark erosion. When the work material (Anode) and electrode (Cathode) the spark is produced between them. The work material is dumped into the dielectric fluid. Die-electric fluid is liquid medium; it does not conduct electric current. There are various type of dielectric fluid like petroleum based, synthetic and vegetable based. Also Electric Discharge machine have various type which are based on the type of machining the work piece. The EDM types like micro EDM, Die- sinking EDM and Wire-cut EDM.

Nomenclature

DOE	Design of Experiment
MRR	Metal Removal Rate
SR	Surface Roughness
EWR	Electrode Wear Rate
ROC	Radial Over Cut
EDX	Energy Dispersive X-Ray Spectroscopy
EDS	Electro dispersive X-ray spectroscopy PMEDM
	Power Mixed Electric Discharge Machining SEM
	Scanning Electron Microscope
CEDM	Cryogenically Cooled Electrode
WECEDM	Wire Electro-Chemical Electric discharge machine

1.1. Various researches

Yan- Cherng Lin et al investigated the performance of machining of conductive (Al_2O_3 + 30 vol% TiC) by using EDM. They discussed about the EDM machining parameters like machining polarity, peak current, auxiliary current, pulse duration, no load voltage and servo reference voltage. The Taguchi experimental method based on L_{18} orthogonal

array was chosen and statistically analyzed by ANOVA to determine the EDM machining characteristics. They conclude Conductive ceramic in machined by EDM process, Metal removal rate is increased with peak current and pulse duration because of more deliver in discharge energy to machining area to aware effect of thermal erosion like melting, thermal spalling, vaporization on EDM process [4]. Maninder Pal Singh et al investigated radial over cut (ROC) using rotary EDM by machining of Al/Al_2O_3 composite with single channel tube tool. To machine Al/Al_2O_3 composite, a brass single channel tube used as tool by electric discharge machining. Peak current, pulse on time, pulse off time and voltage are input parameter and machining method injectection type flushing. S/N ratio graphs and mean effect plot are used to optimize the parameters of Rotary EDM on Al/Al_2O_3 using Taguchi method. [8]

2. Effect of MRR and EWR in Spark EDM

A. Muttamara et al published the paper in title " Effect of electrode material on electrical discharge machining of Alumina" lots of industrial filed are demanded to machine the insulating ceramic materials but Si_3N_4, SiC, and Zro_2. are machined in Electrical discharge machining EDM successfully. Also while machining the Al_2O_3 ceramics indeterminate discharge is occurs and obtain the low quality machining properties. Electrode like Copper, graphite (Poco EDM-3) and copper-infiltrated-graphite (Poco EDM-C3) machine alumina. EDM-C3 very good result in machine 95% pure alumina by EDM and gives High MRR and less TWR over the EDM-3 and copper electrode. They found that 60% in EDM-3 and 80% in EDM-C3 is increase with the positive polarity in MRR. The conclusion is element of copper is not observed on with EDM-3 and EDM–C3 conductive layer and surface resistivity of conductive layer is less in EDM-3 over the EDM-C3. Positive polarity of EDM-C3 improve surface roughness 25µm [5].

S.Suresh kumar et al investigated the parameters like Pulse on time, pulse duty factor, pulse current and voltage by machining of EDM against the composite of Al (6351) - 5 wt% silicon carbide (SiC) 5 wt% boron carbide (B_4C). The aim of the paper to reduce Tool wears ratio (EWR), Power consumption (PC) and Surface roughness (SR). Their practical outcome response was good ability by pulse current with contribution of TWR- 33.08%, SR-76.65% and 48.08% of PC. They summarised that increases the pulse current the tool electric spark energy discharge is also increased and make TWR to increase. And while increase pulse current and pulse duty can less the power consumed [6].

N. saha et al investigated the electrical and non- electrical parameters of sintered the silicon carbide (SiC) of 5- 20 wt% in zirconium diboride composites. They kept the parameters of input as fixed and studied machining performance as well as Metal removal rate (MRR) and as they concluded, when the SiC weight percentage is more MRR become less due to the increase in composite resistivity [7].

2.1. Effect of MRR and EWR in rotary EDM

All the rotating modes of tool give more MRR than the stationary modes. Also MMR increase if peak current of tube electrode is passed to the hollow cross section tube. In case Positive polarity in composite of SiC/6025 Al (20 vol. % SiC) MRR was higher when compare to electrode in negative polarity [10]. M. Ghoreishi and J. Atkinson [16] observed that MRR is increased when the increasing speed of rotational. And also by increasing only the amplitude, the MRR is increased in vibro-rotory. B. Mohan et al examined (by machining Al – SiC composite) that MRR was higher in rotary tool EDM than Stationary tool EDM for any current given. Increase in pulse duration causes decrease in MRR, and low surface vaporization when short pulse duration, also plasma channel to expand and energy density for workpiece is decrease in case of long pulse duration.[17]. P.Kuppan et al [13] evaluated the effect of peak current is examined in graph of MRR versus peak current at various pulse duration .It detailed that Increase in MRR with current increase, when Inconel 718 work is drilled with copper tool and EDM oil dielectric fluid is used at pulse duration of t_o=60µs. And the MRR developed from 4.445 mg/min to 109.98 mg/min as current from 2A to 10A.If pulse duration decreased and peak current increased the EWR may be increased more EWR will occur in case of more peak current. And also from the graph of EWR vs. Pulse duration with respected to polarities, experimental result by C.C.Wang and B.H.Yan [12] shows under negative polarity EWR is more (if work piece is cathode and anode for electrode) compare to positive polarity.

2.2. Effect of MRR in micro EDM

In both the sinking and milling micro-EDM, there is Increase in MRR by increasing the Powder concentration. Also if spark gap is increased and lack of stability is decreased, MRR is increased in the responsibility of powder-

mixed micro-EDM [9]. K.Liu et al discussed that because of negative polarity in S-EDM more MRR in less strict type pulse and smoothness surface was gained in case of iso- energetic type pulses usage when machine Si_3N_4- TiN with Tungsten carbide electrode. And they also discussed, in S-EDM and iso –energetic pulses, material removal mechanism of melting can control as well as formation of regular craters is mare in case of long discharge current timing and higher input energy [11]. B.H.Yan and C.C.Wang [12] summarized after different machining process of work material of 10 vol% Al_2O_3/6061 Al with tool material of copper. Negative polarity in work material (i.e. the cathode) and positive polarity in electrode (i.e. anode) then MRR become higher. And in their investigation they understood in the same condition, more discharge energy and using negative polarity (I_p>3A or τ_{on}>5µs) the MRR was higher. As well as discharge energy was less and using positive polarity (I_p<3A or τ_{on}<5µs) the MRR was higher.

2.3. Effect of MRR powder mixed EDM

Murahari Kolli and Adpu kumar experimented in Ti-6A-4V by electrolyte copper with B_4C powder mixed with EDM oil as dielectric and observed that when B_4C powder concentration is increase, MRR also increase[15].H.K. Kansal et al (2007) [18] used powder mixed electric discharge machining to compare the experimental and theoretical MRR. And determined melting temperature is lesser than the temperature in the profile when work material is carbon high chrome die steel (AISI D2). Nihal et al (2016) [19] used hydroxyapatite powder mixed to machine Ti6Al4v workpiece and found that random removal of workpiece and microcracks are formed when pulse time 100µs and pulse current 12A.

2.4. Effect of MRR Wire EDM

Kuan Yuan kuo et al [24] used WECDM to machine quartz glass in 5x7x1 mm^3 with graphite electrode 16x16x5 mm^3. Fig shows that cutter mark forms in case of higher feed rate and shortest feed depth as shown in Fig.1

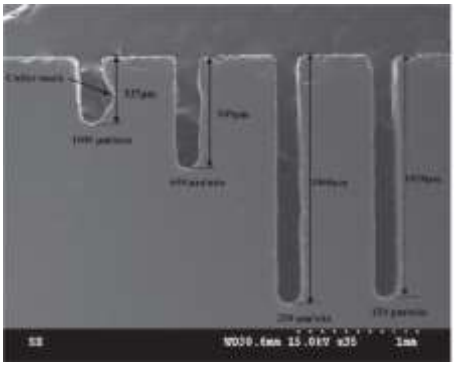

Fig. 1 SEM image of slit depth obtained when feed rate is different.

3. Surface Characteristics of Composite Material

K. M. Patel et al published a paper under title ”Optimum Parametric Combination Using a Surface Roughness Prediction Model for EDM of Al_2O_3/SiCw/TiC Ceramic Composite” , the most popular ceramic material like alumina was using over the wear resistiance and structural applications because of alumina physical characteristics. The materials is difficult and results it decrease the usage due materials advantage in brittleness and less fracture toughness. Aim of K. M. Patel et al is to include SiC whisker, TiC particles into Al_2O_3 achieved single phase alumina ceramic for getting improvement in mechanical properties. They conclude two stage effort of obtaining Surface Roughness by Response Surface methodology better useful method of obtaining process parameter to improve surface quality, dominant parameter influencing Surface Roughness (SR) by pulse – on time and observed in SR is increase by means of increasing the discharge current [3].

Jahan et al understood that the Increase in powder concentration the surface Roughness (SR) average is decrease and if more powder particles concentration then SR average is Increases. They founded that after added the graphite nano-powder in dielectric oil, voltage gap setting and surface roughness average capacitance is decreased [9]. The machining process to deep blind hole of target material of 10 vol% Al_2O_3/6061 Al with electrode material of copper are feed with extended pulse duration cause to plasma channel expand and energy density lowered. And also in target material the cavity occurs on the surface highly but positive polarity cavities are hot identified [12]. Discharge duration (t_e) and the pulse interval time (t_o) are the parameters for input in values of t_e= 5.12µs, t_o=25µs, i_e=8A at the 6th trail

in methodology of DOE, 0.82µm of surface roughness is resulted and there is good improvement in surface quality [11]. A different pulse generated and obtained surface characteristic as show in Fig.2

Fig. 2 Surface characteristics of machined surface using different pulse generators.

B.H. Mohan et al observed that when discharge is increase the surface roughness is also increase. Fig.3 (a) (b) shows the variation of discharge current and R_a of Al-20% SiC and Al-25% SiC.

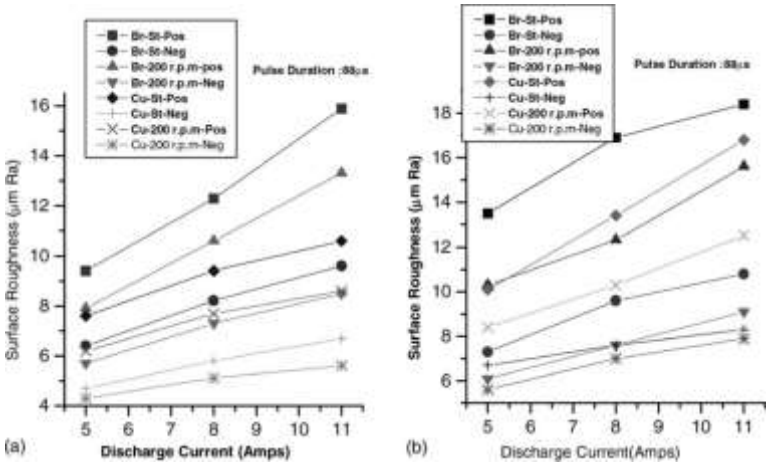

Fig.3 Variation of SR with discharge current (a) Al- 20% Sic: (b) Al -25% SiC

Balbir et al examined the surface characteristics by using scanning electron microscope (SEM), Electro dispersive X-ray spectroscopy (EDS) and Micro – vicker hardness, after machining the AA6061/10% SiC composite with tungsten powder mixed dielectric fluid (PMEDM). Then they observed the effect of parameters on surface characteristics that when the current is increase the surface roughness (SR) is also increase. As well as surface finish quality is good in tungsten powder mixed EDM compare with Normal EDM. [20]

4. Aerosol emission

S.Thiyagarajan et al experimented and analyzed the aerosol emission rate in three material viz., mild steel, aluminum and tool steel Fig 3. They observed that aerosol emission is lower in aluminum while compare to mild steel. [21]

Eubank et al [22] studied the aerosol constituents for aluminum, iron, and chromium as work material. And described the iron: copper ratio is lower than aluminum: copper ratio Fig 4. Carbon and hydrocarbon need 30-40% of aerosol sample are also explained by them. Fig shows the gas chromatogram of aerosol sample which resulted by s.p.sivapirakasan [23] by machining Iron, chromium copper.

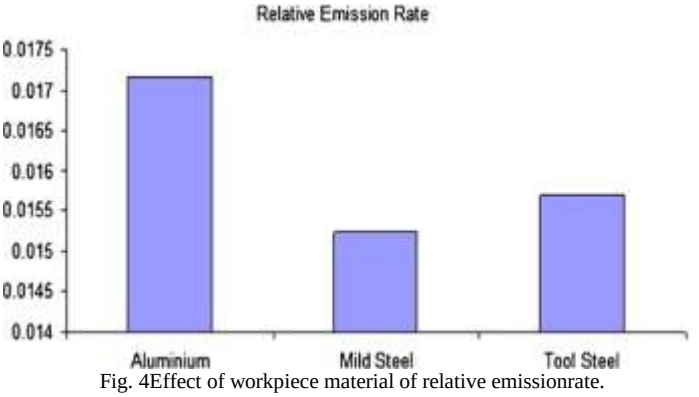

Fig. 4Effect of workpiece material of relative emissionrate.

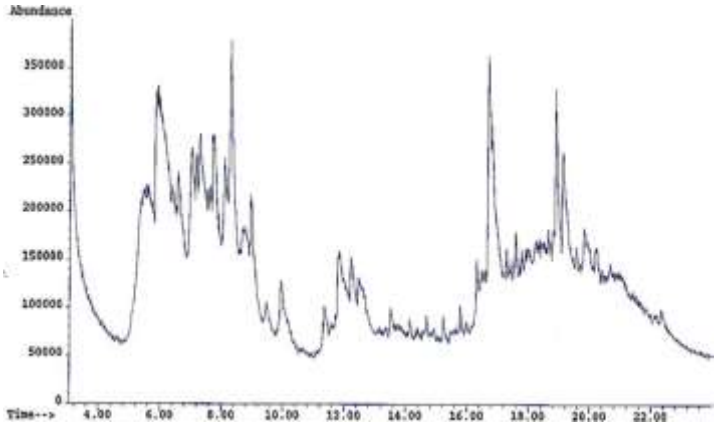

Fig. 5Gas chromatogram of aerosol sample (current 7A, pulse duration 261_s, dielectric level 40mm, and flushingpressure 0.7 kg/cm2).

Krishna kumar saxena et al [25] studied the removal mechanism in micro EDM of silicon of silicon carbide and EDX analysis is used. They observed after analysis, cu and Al formation on the machined workpiece. Fig .5 shows EDX result made by them**.**

a

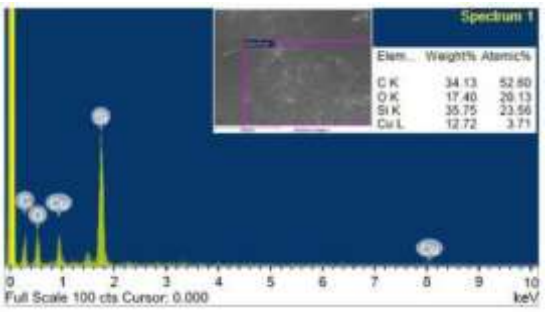

Fig .6 EDX analysis microEDM of Silicon carbide SiC (a) formation of cu (b) formation of Al

Vineet srivastava and pulak M. pandey [26] observed there is no cu formation in the EDMed machined surface of workpiece M2 grade HSS, Because kerosene dielectric separated the carbon from the workpiece. In case of CEDM process there is no change in mechanism and MRR but compared to EDM, more ignition was taken as shown in above Fig 6 (a) (b) .

5. Past Research objectives

Many researches are done in EDM from 1993. Each and every research there was some new concept was introduced and implemented. The objective and research results are detailed charted in Fig.7

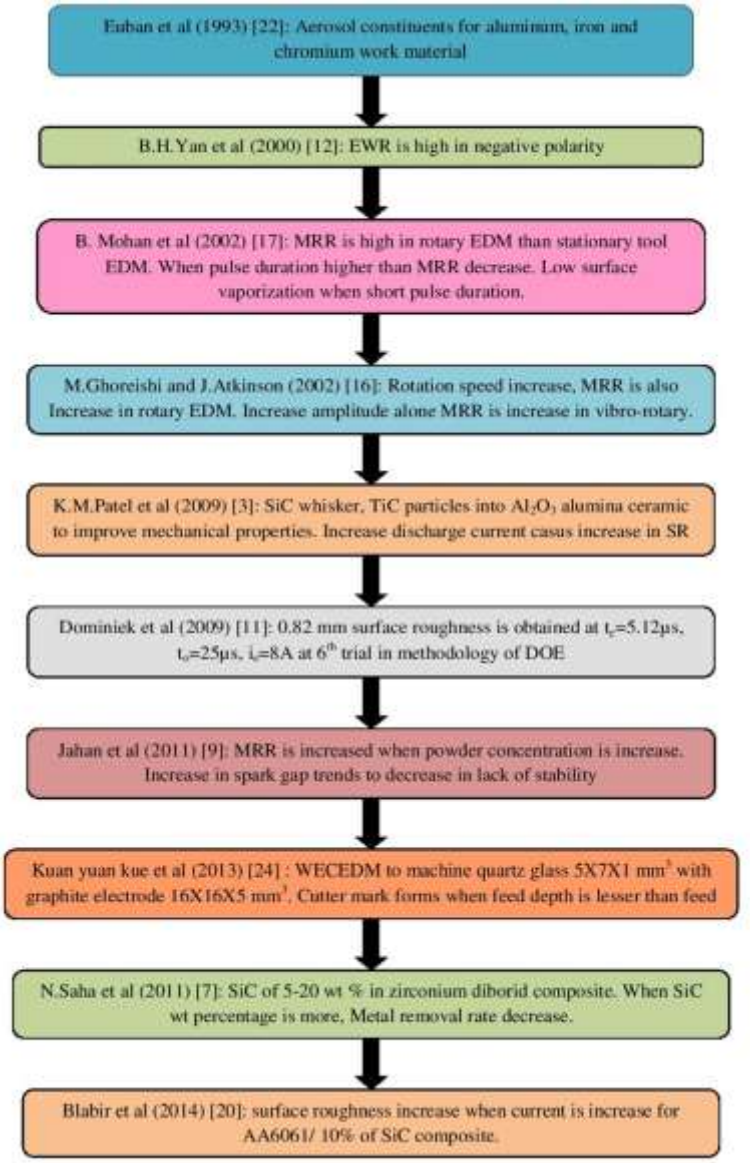

Fig.7 Past research objectives.

6. Conclusion

- In this review the composite materials and industrial demand materials which are machined EDM is detailed explained the effect of parameter.
- The materials like Al2O3/ SiC / TiC composite are very demand in Industries to machine. In this review, it is clearly explained which type EDM and what are the parameter to concentrate for this composite to get better output is discussed.
- Al_2O_3/ 6061 Al, tool steel are very difficult to machine when it is in complex structure. A review describe the way and better machining process for this type of material.

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