

A REVIEW STUDY ON ELECTRO DISCHARGE MACHINING ON Al-SiC COMPOSITES

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ABSTRACT

Manufacturing industries are facing difficulties from newly developed, advanced materials viz. composites, ceramics and super alloys, which fall under the category of difficult-to-machine materials. To overcome these challenges, non-conventional machining processes are being employed which give better material removal rate, accuracy and surface finish. Electrical Discharge Machining (EDM) is the process in which electrically conductive materials are machined irrespective of their hardness using controlled sparks in the presence of dielectric. Aluminium Metal Matrix Composites (AMMC's) are new generation engineering materials that possess superior physical and mechanical properties compared to non-reinforced alloys. This paper presents a review of research work done on Al-SiC metal matrix composite on EDM, Wire EDM, Powder Mixed EDM, EDM in Water, Micro EDM. The paper also discusses the future scope of work in the same area.

Keywords: Electrical Discharge Machining, Metal Matrix Composites, Metal Removal Rate, tool Wear.

1. Introduction

The advanced materials have attractive properties i.e. high strength, high bending stiffness, good damping capacity, low thermal expansion, better fatigue characteristics which make them potential material for modern day industrial application. Present manufacturing industries are facing challenges from these advanced materials viz. super alloys, ceramics, and composites, that are hard and difficult to machine, requiring high precision, surface quality which increases machining cost. To meet these challenges new processes with advanced methodology and tooling needs to be developed.

Electro discharge machining is one of the oldest and most commonly used non-traditional machining process. Machine shops are starting to consider EDM in place of traditional machining methods and to use EDM to complement existing grinding and milling machines. Composites are now used in aircraft, helicopters, space-craft, satellites, ships, submarines,

automobiles, chemical processing equipment, sporting goods and civil infrastructure, and there is the potential for common use in medical prosthesis and microelectronic devices. Composites have emerged as important materials because of their light-weight, high specific strength and stiffness, excellent fatigue resistance and outstanding corrosion resistance compared to most common metallic alloys such as steel and aluminium.

2. Principle of EDM

Electro Discharge Machining (EDM) is an electro-thermal machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. EDM is mainly used to machine difficult to machine materials and high strength temperature resistant alloys and composites. EDM can be used to machine difficult geometries in small batches or even on job-

shop basis. Electric discharge machining, sometimes colloquially also referred to as spark erosion machining, is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks). Material is removed from the workpiece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the "tool" or "electrode", while the other is called the workpiece-electrode, or "workpiece".

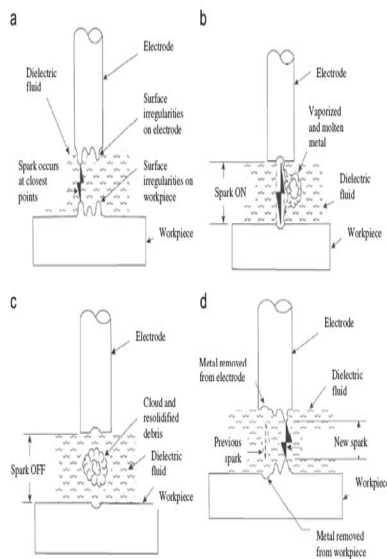


Figure.1: Step of different incidence in EDM

3. EDM on Composites

Die-sinking (also known as ram) type EDM machines require the electrode to be machined in the exact opposite shape as the one in the workpiece. The EDM process is most widely used by mold making tool and die industries, but becoming a common method of making prototype and production parts especially in the aero space, automobile and electronics industries.

The important performance characteristics of EDM are material removal rate (MRR) and surface finish. The process variables that influence the MRR and surface finish are pulse duration (Ton), pulse interval (Toff), duty cycle, spark gap size, voltage, dielectric fluid pressure and tool materials. This paper summaries some of the previously attempted research works on machining Al-SiC metal matrix

composites, study of effect of process parameters and optimization.

Debaprasanna et. al[12] investigated on machinability characteristic of aluminum silicon carbide composite on electrical discharge machine by taking six process parameters such as Discharge current, Pulse-on-time, Duty cycle, Flushing pressure (bar), SiC (wt.%) and particle size in micron and found out the optimum values through PCA approach. From the statistical analysis, it is observed that the process parameter such as discharge current, pulse-on-time, duty factor, and flushing pressure have the significant effect on the multi performance characteristic (MPCI). The effect of weight percentage and mesh size of silicon carbide in MMC has relatively less contribution in improving MPCI. Treating MPCI as an equivalent single response, the MPCI value is analyzed by Taguchi's method. From the response plot, it is found that the optimal setting is discharge current of 1 amp, pulse-on-time of 200 μ s, duty cycle of 85%, flushing pressure of 3.9226 bar, 15% of SiC, and 300 mesh size. With this optimal setting, the optimal values of responses such as MRR, TWR, surface roughness and circularity are found as 14.376 mm³/min, 0.018 mm³/min, 3.043 μ m and 0.970 respectively. The study demonstrates that a difficult-to machine material like can be easily machined EDM with improved quality characteristics.

Samesh h.Habib [11]: This paper developed mathematical model for influences of various electrical discharge machining parameters through response surface methodology (RSM), utilizing relevant experimental data. The adequacy of the proposed models have been tested through the analysis of variance (ANOVA). Optimal combination of these parameters was obtained for achieving controlled EDM of the metal matrix composite work pieces. This study concludes that metal removal rate increases with an increase of pulse on time, peak current and relatively with gap voltage. Metal removal rate decreases with increase of SiC percentage. Electrode wear ratio increases with an increase of both pulse on time and peak current and decreases with increase of both of SiC percentage and gap voltage. The gap size decreases with the increase of SiC percentage and increases with the increase of pulse on time, peak current and gap voltage. Finally, the surface roughness increases with the increase of pulse on time, SiC percentage, peak current and gap voltage. Investigations were carried out for analysis of the control conditions needed for the control of the material removal rate, electrode

wear ratio, gap size and surface roughness. The models reflect the complex, interactive and higher order effects of the various predominant process parameters, e.g. the pulse on time, peak current, average gap voltage and SiC percentage on the respective material removal rate, electrode wear ratio, gap size and surface roughness criteria, as has been justified through the various experimental analyses and test results.

S. Assarzadeh et al[1] In this paper, attempts have been made to model and optimize process parameters in Electro-Discharge Machining (EDM) of tungsten carbide-cobalt composite (Iso grade: K10) using cylindrical copper tool electrodes in planing machining mode based on statistical techniques. Four independent input parameters, viz., discharge current (A: Amp), pulse-on time (B: μ s), duty cycle (C:%), and gap voltage (D: Volt) were selected to assess the EDM process performance in terms of material removal rate (MRR:mm³/min), tool wear rate (TWR: mm³/min), and average surface roughness (Ra: μ m). Response surface methodology (RSM), employing a rotatable central composite design scheme, has been used to plan and analyze the experiments. For each process response, a suitable second order regression equation was obtained applying analysis of variance (ANOVA).

R. Karthikeyan et al[3] In this paper an attempt has been made to develop mathematical models for optimizing electric discharge machining (EDM) characteristics such as the metal removal rate (MRR), the tool wear rate (TWR) and the surface roughness (CLA value). The process parameters taken in to consideration were the current (I), the pulse duration (T) and the percent volume fraction of SiC (25 m size) (V) present in LM25 aluminium matrix. The analysis of the experimental observations show that the MRR, the TWR and the surface roughness are greatly influenced by the percent volume of SiC present in MMCs, by the current and by the pulse duration. The MRR increases with an increase in the current and decreases with an increase in the percent volume of SiC and the pulse duration, whilst the TWR increases with an increase in the current and the percent volume of SiC, but decreases with an increase in the pulse duration. The surface roughness increases with an increase in the current, the percent volume of SiC and the pulse duration.

H. Hocheng et al[6] This paper presents the correlation between the major machining parameters, electrical current and on-time, and the crater size produced by a single spark for the representative

material SiC/Al. The experimental results not only show the predicted proportionality based on heat conduction model, but are also compared with common steels regarding the material removal rate. Based on the obtained knowledge, one can proceed to the study of machinability of MMC by EDM for optimal production cycle. The material removal rate is proportional to the applied current and on-time. The crater size of SiC/Al is larger than steel. In the continuous discharge analysis, one finds the discharge of SiC/Al is more irregular, and the material removal rate is faster at the beginning followed by being retarded due to the existence of SiC particles in the gap. As closed-loop gap control is applied, the material removal rate is greatly improved as expected. For effective EDM of SiC/Al, large current and short on-time are recommended .

B. Mohan et al[4] In this study the machining characteristics of SiC/6025 Al composite using rotary electro-discharge machining (EDM) with a tube electrode were investigated. Brass was used as the electrode material to EDM SiC/6025 Al composites. Three observed values: material removal rate (MRR), electrode wear rate (EWR) and surface roughness (SR) are adopted to evaluate the machinability. Peak current ,polarity, volume fraction of SiC reinforced particles, pulse duration, hole diameter of the tube electrode, and speed of electrode rotation were used as the input variables to assess the machinability.

Chinmaya P Mohanty et al[10] This paper proposes an experimental investigation and optimization of the various machining parameters for the electrical discharge machining (EDM) processes on Inconel 718 super alloy using a multi objective particle swarm optimization (MOPSO) algorithm. A Box-Behnkin design of response surface methodology has been used to collect data for the study. The machining performances of the process are evaluated in terms of material removal rate (MRR) and surface quality which are functions of process variables such as open circuit voltage, discharge current, pulse-on-time, duty factor, flushing pressure and tool material. Mathematical model is developed relating responses with process variables. Finally, a MOPSO algorithm has been proposed for the multi objective optimization of the responses. The analysis of experimental observations revealed that tool material and discharge current and pulse-on-time are the important parameters in the machinability of Inconel 718 super alloy for both the responses.

Chinmaya P Mohanty et al[20] This paper proposes an experimental investigation and optimization of various machining parameters for the die-sinking electrical discharge machining (EDM) process using a multi-objective particle swarm (MOPSO) algorithm. The responses used in the analysis are material removal rate, electrode wear ratio, surface roughness and radial overcut. The machining parameters considered in the study are open circuit voltage, discharge current, pulse-on-time, duty factor, flushing pressure and tool material. Finally, a MOPSO algorithm has been proposed for simultaneous optimization of multiple responses. Mutation operator, predominantly used in genetic algorithm, has been introduced in the MOPSO algorithm to avoid premature convergence. The Pareto-optimal solutions obtained through MOPSO have been ranked by the composite scores obtained through maximum deviation theory to avoid subjectiveness and impreciseness in the decision making.

3. Wire EDM on Composites

Wire electro discharge machining (WEDM) is the process that produces a thin kerf around the wire by spark erosion as the wire travels through the workpiece in the presence of dielectric fluid. Unlike EDM the dielectric is sprinkled into the cutting zone rather emerging it in the dielectric. Since no mechanical forces are involved in WEDM it finds its application in machining of many delicate parts. On the other hand very hard materials can also be machined irrespective of their hardness if they are conducting. The process is influenced by parameters such as pulse on time, pulse off time, peak current

Wire Electric Discharge Machining (WEDM) is one of the greatest innovations affecting the tooling and machining industry. This process has brought to industry dramatic improvements in accuracy, quality, productivity and earnings. Before Wire EDM, costly processes were often used to produce finished parts. Now with the aid of a Computer and Wire EDM machines, extremely complicated shapes can be cut automatically, precisely and economically, even in materials as hard as c In 1969, the Swiss firm Agie produced the world's first Wire EDM machine. These machines are equipped with automatic wire

threading and can cut over 20 times faster than the beginning machines. During the wire EDM process, the wire carries one side of an electrical charge and the workpiece carries the other side of the charge. When the wire gets close to the part, the attraction of electrical charges creates a controlled spark, melting and vaporizing microscopic particles of material. The spark also removes a miniscule chunk of the wire, so after the wire travels through the workpiece one time, the machine discards the used wire and automatically advances new wire. The process takes place quickly—hundreds of thousands of sparks per second but the wire never touches the workpiece. This section presents the various notable research trends carried out in the field of Wire EDM of AMMC's. Gatto and Iuliano [26] performed tests on WEDM on Al Alloy/SiC with 15% whiskers and 30% particles reinforcement under one roughing and two finishing conditions. Some roughed and some finished surfaces were glass bead peened. During the machining of both composites the machined surfaces their sections and profiles were examined by SEM to understand the reinforcement and the behavior of the matrix. Rozenek et al. [27] conducted experiment on AlSi7Mg/SiC and AlSi7Mg/Al₂O₃ to investigate the effect of machining parameters on the machining feed rate and surface roughness of WEDM. The machining feed rate of WEDM cutting composites significantly depends on the kind of reinforcement. The maximum cutting speed of AlSi7Mg/SiC and AlSi7Mg/Al₂O₃ are approx. 3 times and 6.5 times lower than the cutting speed of Al alloy. Samy et al. [28] developed a mathematical modeling for WEDM of Al-SiC composites. They optimized WEDM characteristics such as MRR, cutting speed and the SR was developed. The process parameters considered are the average machining voltage, pulse frequency, workpiece height, kerf size and the percentage volume fraction of SiC present in the Aluminium Matrix. Yan et al. [29] experimented WEDM by using Al6061/Al₂O₃ of 20 vol.% into the locations of broken wire and the reason for wire breaking in machining. Results indicated that the cutting speed (MRR), the surface roughness and the width of the slit of cutting test material depends on volume fraction of reinforcement and also that in machining Al6061/Al₂O₃ composites a very low wire tension, a high flushing rate and a high wire speed are required to prevent wire breakage an

appropriate servo voltage, a short pulse on time and a short pulse off time which are normally associated with a high cutting speed, have little effect on the surface roughness. Manna and Bhattacharya [30] investigated the parameter setting during the machining of Aluminium reinforced silicon carbide AMMC and the Taguchi method was used to optimize the CNC wire cut EDM parameters and L18 orthogonal array was used. From experimental results and through ANOVA and F-test values, the significant factors are determined for each machining performance criteria, such as the MRR, SR, gap current and spark gap (gap width). Mathematical models relating to the machining performance are established using the Gauss elimination method for the effective machining of Al/SiC MMC.

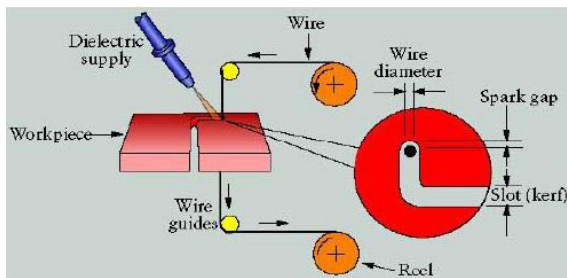


Figure 2: Schematic Diagram of Wire EDM

Patil and Brahmankar [31] performed experiments on performance of Al/SiCp composites with WEDM using Taguchi method. Based on experimental results, mathematical models relating the machining performance and machining parameters were developed. Optimal settings for each performance measure have also been investigated. A comparative study on unreinforced alloy revealed the effect of reinforcement. Cutting speed for unreinforced alloy was found higher compared to composites but whereas surface finish in composites was found superior compared to the unreinforced alloy. Wire breakage posed limitations on the cutting speed of composite. Ganpatrao et al. [32] studied about the determination of MRR of WEDM of Metal Matrix Composites using Dimensional analysis. They proposed Semi-empirical model of MRR in WEDM based on thermo physical properties of the workpiece and pulse on time, average gap voltage. An empirical model based on response surface method was developed. Satishkumar et al. [33] investigated the

effect of WEDM machining parameters such as pulse-on time, pulse-off time, gap voltage and wire feed on MRR and SR in AMMCs consisting of aluminum alloy (Al6063) and SiCp. The Al6063 is reinforced with SiCp in the form of particles with 5%, 10% and 15% volume fractions. The experiments were carried out as per design of experiments approach using L9 orthogonal array. These results were analyzed using ANOVA and response graphs. The results were also compared with the results obtained for unreinforced Al6063. From the study, it was found that different combinations of WEDM process parameters are required to achieve higher MRR and lower surface roughness for Al6063 and composites. Generally, it was found that the increase in volume percentage of SiC resulted in decreased MRR and increased SR. Regression equations were developed based on the experimental data for the prediction of output parameters for Al6063 and composites. Pragya Shandilya et al. [34] optimized the process parameters during machining of SiCp/6061 Aluminium MMC by wire electrical discharge machining (WEDM) using Response Surface Methodology (RSM). Four input process parameters of WEDM namely servo voltage (V), pulse-on time (Ton), pulse-off time (Toff) and wire feed rate were chosen as variables to study the process performance in terms of cutting width (kerf). In addition mathematical models were also developed for response parameter. Properties of the machined surface had been examined by the Scanning Electron Microscopic (SEM). Input process parameters had been found to play a significant role in the minimization of kerf. ANOVA results showed that voltage and wire feed rate were highly significant parameters and pulse-off time was less significant. Pulse-on time had insignificant effect on kerf. For targeted value of kerf the optimized values of servo voltage was 70.06 V, pulse-on time was 2.81 μ s, pulse-off time was 7.79 μ s and wire feed rate was 8.90 m/min. SEM images of the cut surfaces revealed that the fine surface finish was obtained when machining was done at a combination of lower levels of input process parameters. Rajaneesh N. Marigoudar et al. [35] emphasized in their work on behavior of zinc aluminium alloy reinforced with silicon carbide particles when machined with wire electric discharge machining process (WEDM). The

workpiece material used was ZA43 reinforced with SiCp. MMC was fabricated by liquid metallurgy technique. MMC with three different reinforcement percentages 5%, 10% and 15% were casted in the form of cylindrical specimen. The fabricated cylindrical specimens were machined i.e. sliced in transverse direction. Machining was carried-out by varying applied current of (2, 4 and 6amp.), pulse on time (4, 8 and 16 μ s) and pulse off time (5, 7 and 9 μ s) while other parameters such as voltage, dielectric flushing pressure, wire tension etc. were maintained constant. It was observed that there was a reduction in the material removal rate and increase in surface roughness for increasing reinforcement percentage in the composite. Material removal rate decreased with increase in reinforcement content in MMC. For same value of current and pulse on time, MMC with 5% SiC took less time and with 15% SiC took more time to slice the bar. It was thus concluded that to get higher material removal rate, higher currents and higher value of pulse on time had to be used for machining. The quantity of SiC in MMC was also influencing parameter on surface roughness. Higher the quantity of SiC, higher will be the surface roughness. It was also observed that applied current and pulse on time increased the material removal rate whereas pulse off time had less effect on it.

Sanjeev KR. Garg et al. [36] experimentally investigated the machining characteristics and the effect of wire EDM process parameters during machining of newly developed Al/ZrO₂ Particulate Reinforced Metal Matrix Composite Material (PRMMC). Central Composite Design (CCD) of Response Surface Methodology (RSM) considering full factorial approach had been used to design the experiments. The input parameters considered for optimization were pulse width, time between pulses, servo control mean reference voltage, short pulse time, wire feed rate and wire tension. The response measures considered were cutting velocity and surface roughness. The multi optimization results obtained by initial parameters setting, response surface methodology and grey relational techniques had been compared and validated by confirmation experiments. The comparison of performance characteristics using different wire electrode was also carried out. It was found that diffused wire electrode provided better performance results related to cutting velocity, surface roughness breakage as compared to

brass wire electrode. The optimal machining conditions for multi-objective optimization were pulse width=1.14 s, time between pulses=4.61 μ s, short pulse time=0.7 μ s, servo control mean reference voltage=50 volts, wire feed rate=11.1 m/min and wire tension=0.43 daN. The value of performance measures obtained were cutting velocity=8.234 mm/min and surface roughness =1.803 μ m. The values of the performance measures proved that the newly developed MMC could be effectively machined by wire EDM. Ganpatrao et al. [38] studied effect of Al₂O₃ particulate reinforced Aluminium matrix composites on WEDM. The effect of combination of reinforcement, current, pulse on time, pulse off time, servo reference voltage, maximum feed speed, wire speed, flushing pressure and wire tension on cutting speed, surface finish and kerf width was determined by Taguchi orthogonal array. The optimum machining parameter combinations were obtained for surface finish, cutting speed and kerf width separately. Lal et al. [39] conducted experimental study on WEDM of Al7075/SiC/Al₂O₃ hybrid composite fabricated by inert gas assisted electromagnetic stir casting process. The objective of the paper was to investigate the effect of WEDM process parameters like discharge duration, pulse interval time, discharge current and the wire drum speed on the kerf width while machining newly developed hybrid metal matrix composite Al7075/7.5%SiC/7.5% Al₂O₃. The discharge current has most significance on kerf than discharge duration.

Ashish Srivastava et al. [40] presented an experimental study on composite of Al2024 reinforced with SiC to investigate the effects of Wire Electric Discharge Machining (WEDM) for three levels of each parameter such as current, pulse on time and reinforcement percentage on surface finish and Material Removal Rate (MRR). Response surface methodology (RSM) technique had been applied to optimize the machining parameters for minimum surface roughness and maximum MRR. The reinforcement percentages of SiC were taken as 2%, 4% and 6%. From the Scanning Electron Microscopy (SEM) images of machined samples it was observed that the surface finish that a nonconventional machining process gave was better than the surface finish we got from the conventional machining process. Results of experiments showed

that surface roughness increased with the increase in pulse on time, peak current and reinforcement percentage while MRR increased with the increase in pulse on time, peak current and decreased with the increase in reinforcement percentage. Anand Sharma et al. [41] experimentally investigated the impact of process parameters namely pulse on time, pulse off time, peak current and servo voltage on cutting rate using WEDM on Al6063/ZrSiO₄ 5% of wt. metal matrix composite. An experimental plan of the Box-Behnken based on the Response Surface Methodology (RSM) was applied to perform the experimentation work. The mathematical relationships between WEDM input process parameters and response parameter are established to determine optimal values of cutting rate mathematically. The ANOVA and F-test are performed to obtain statistically significant process parameters. The generated optimal process conditions have been verified by conducting confirmation experiments and predicted results were found to be in good agreement with experimental findings. It was found experimentally that increasing the pulse on time and peak current, the cutting rate increased, whereas increasing the pulse off time and servo voltage decreased the cutting rate. Surface topography of the machined surface showed that large size craters and cracks were formed on the surface when pulse on time was increased to a high level and pulse off time was kept at a lower level.

4. Powder Mixed EDM on Composites

The major problem to use EDM for large scale production is its low machining rate and poor surface finish. Many advances have come in the field of EDM to overcome these difficulties. One of those advancements is powder mixed EDM (PMEDM). Even though, the principle of PMEDM is not completely understood, the results of the experiments done by many researchers have shown significant improvement in material removal rate (MRR) and surface quality. Among the powder materials, aluminum produced better MRR and good surface finish compared to other materials like Cr, Cu and SiC. This was attributed to the increased spark gap due to aluminum's high electrical conductivity and low density. Kerosene or some commercial EDM oil

was widely used as the dielectric medium in PMEDM. However, the Multi objective optimization of PMEDM process was performed by Kansal et al. [42]. They carried out an experimental study of the machining parameters in Powder Mixed Electric Discharge Machining (PMEDM) of Al/10%SiCp metal matrix composites and observed that MRR increased considerably with an increase in peak current for any value of pulse duration. The SR increased with increase in peak current and pulse duration. Composites and observed that MRR increased considerably with an increase in peak current for any value of pulse duration. The SR increased with increase in peak current and pulse duration. Singh et al. [43] reported the work on EDM with SiC abrasive powder-mixed dielectric, a hybrid process. The machining of Al6061/Al₂O₃p 20% of wt. work specimens has been carried out with copper electrode. An L18 orthogonal array was employed for the optimization of the performance measures such as MRR and SR. The effects of seven control factors (three levels each) and a noise factor (two level), and one two-variable interactions on the responses were quantitatively evaluated by the Length's method. Analyzed results indicate that the process effectively improves the MRR and reduces the surface roughness, in comparison with the conventional EDM. Gangadharudu et al. [44] made an attempt to fabricate and machine Al/Al₂O₃ MMC using EDM by adding Aluminium powder in kerosene as dielectric fluid. Results showed an increase in MRR and decrease in Surface Roughness compared to those for conventional EDM. Semi empirical models for MRR and SR based on machining parameters and important thermo physical properties were established using a hybrid approach of dimensional and regression analysis. A multi response optimization was also performed using principal component analysis-based grey technique to determine optimum settings of process parameters for maximum MRR and minimum SR within the experimental range. The recommended setting of process parameters for the proposed process has been found to be powder concentration =4 g/l, peak current (I) =3 A, pulse on time (Ton) =150 ms and duty cycle =85%.

5. Water EDM on Composites

Water EDM is in which the dielectric fluid is used as deionised water. Using deionised water as the dielectric results in lower machining time as opposed to other fluids. However, Mwangi J.W et al. [45] investigated the effect of using oil and deionised water as the dielectric fluids as well as the effect of introducing low frequency vibration in EDM machining of Aluminium Silicon Carbide (AlSiC) MMC. Experiments were carried out on AlSiC (AMC225XE) material using Sarix-100 high precision micro-erosion machine. A series of experiments were carried out with and without workpiece vibrations. For the experiments with vibrations a vibration frequency of 900Hz was used. The result of this study indicates that the introduction of vibration raises the material removal rate but results to an inferior surface quality.

6. Micro EDM on Composites

In recent years, numerous developments in EDM have focused on the production of micro-features. This has become possible due to the availability of new CNC systems and advanced spark generators that have helped to improve machined surface quality. Also, the very small process forces and good repeatability of the process results have made micro-EDM the best means for achieving high-aspect-ratio micro-features. Current micro-EDM technology used for manufacturing micro-features can be categorised into four different types:

- Micro-wire EDM, where a wire of diameter down to 0.02mm is used to cut through a conductive workpiece.
- Die-sinking micro-EDM, where an electrode with micro-features is employed to produce its mirror image in the workpiece.
- Micro-EDM drilling, where micro-electrodes (of diameters down to 5–10 μm) are used to 'drill' micro-holes in the workpiece.
- Micro-EDM milling, where micro-electrodes (of diameters down to 5–10 μm) are employed to produce 3D cavities by adopting a movement strategy similar to that in conventional milling

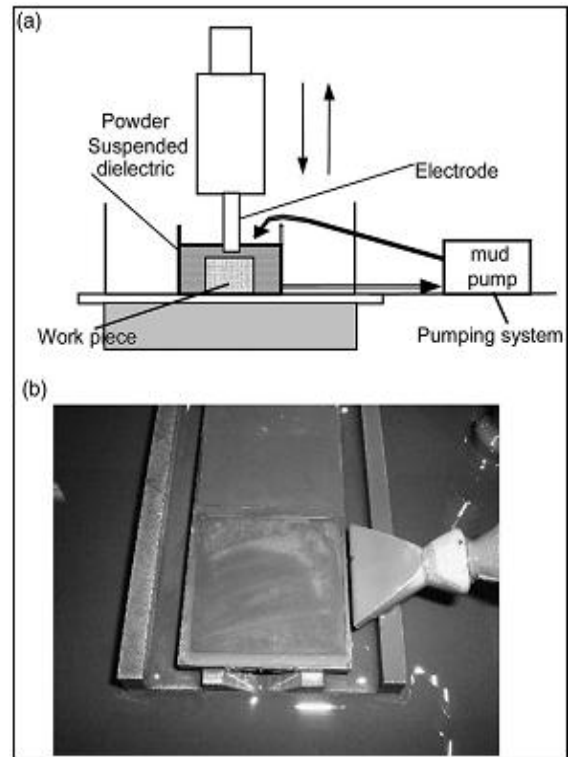


Figure 3: (a) Circulation system schematic view (b) Machined sample with silicon powder suspended on dielectric.

Zhao et al. [46] machined SiCp/Al using micro-EDM. First, a $\Phi 40\mu\text{m} \times 4.1\text{mm}$ micro tool electrode of which the aspect ratio is up to 100 was made; and then, through experiment, the impact of open-circuit voltage and electrode material on processing speed and electrode wear was analyzed; finally, $28\mu\text{m}$ wide micro slits, micro square platform of $34\mu\text{m}$ long on each side and other micro three-dimensional structure were machined. Research and experimental results show that the use of appropriate micro-machining parameters and reasonable processing methods can improve processing performance to better achieve the micro-EDM of SiCp /Al.

7. Conclusion

A Review research work on Aluminium Metal Matrix Composites on Electric Discharge Machining is presented in this paper. Majority of the research was focused on increasing the metal removal rate and

improving the surface finish. The research work of the last 20 yrs has been discussed and the following conclusions are drawn:

1) Most of the work has been done on Aluminium MMC's reinforced with Silicon Carbide (SiC) particulate and on Alumina (Al₂O₃), due to their reinforcement in Aluminium composites for its excellent combination of physical properties, availability and low cost of the particulate.

2) Much less work has been done on Aluminium MMC's reinforced with Si₃N₄, ZrB₂, B₄C, SiO₂, B, AlN, BN, due to their rare utilization and cost. Aluminium Composites reinforced with those particulates may also be considered as future scope.

3) Mostly, the work has been carried out on AMMC's using EDM and Wire EDM, less work has been done on other types of EDM.

4) Review revealed that, Water EDM resulted in the high MRR but it shows the poor Surface quality.

5) Micro EDM and Powder Mixed EDM indicates the improvement in the MRR and good surface finish compared to other types. More work could be done on Micro EDM and Powder Mixed EDM in future and there is enormous scope for research work in this area.

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