MACHINING OF METAL MATRIX COMPOSITES BY EDM AND ITS VARIANTS: A REVIEW

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Abstract: *Nowadays the keen interest of the automobile and aerospace sector on metal matrix composites (MMCs) is increasing due to is attractive mechanical properties and applications. The machining of MMCs by advance machining process is the relatively new field of attention for researchers and scientist as conventional machining of MMCs is complex and difficult. Electric discharge machining (EDM) is widely used process among advance machining process for machining MMCs. This research work investigates different variants of EDM for machining the wide range of MMCs. The effect of process parameters (spark gap, pulse current, duty cycle etc.) on response parameter such as material removal rate (MRR), tool wear rate (TWR), surface finish (SR) etc. during the machining of different MMC martials with different variants of EDM were studied under this review paper.*

Key words: *EDM, MMC, TWR, process parameters, response parameters*

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1. Introduction

MMCs are an interesting type of metal that combine the distinct characteristics of two or more materials resulting in physical and mechanical properties that are otherwise impossible to obtain (Kainer, 2006). MMCs generally consist of lightweight metal alloys of aluminium, magnesium or titanium reinforced with ceramic particulate, whiskers, or fibres (Yan & Wang, 1998). MMCs are gaining attention for applications in aerospace, defence, and automobile industries. These materials have been considered for use in automobile brake rotors and various components in internal combustion engines. The materials used for these applications generally require lightweight and greater wear resistance than those of conventional materials. One factor that prevents more manufacturers from embracing MMC technology is the difficulty in machining these materials. The machining of MMCs is difficult due to the highly abrasive nature of ceramic reinforcements when traditional machining was used (Monaghan & Reilly, 1992; Yue et al., 1996; Ramulu, 1998). Machining is a process of removing undesirable material from a work piece (raw material) to convert it into desire shape (final product). In traditional machining the undesirable material is removed in the form of chips by the application of force applied by relatively hard cutting tool. High tool wear and poor surface is two main problem encountered during machining of MMCs by traditional machining process due to presence of abrasive particle (reinforcement) (Pramanik, 2014). Machining of MMCs by conventional process is very difficult. So there is need of advance machining process for machining MMCs.

EDM is an extremely prominent machining process among newly developed advance machining techniques. The merits of the EDM technique become most apparent in machining MMCs which have the highest hardness in reinforcement. The EDM process does not involve mechanical energy thus; hardness, strength, or toughness of the workpiece does not affect the MRR. Notably, the EDM process is normally accompanied by tensile residual stress and a heat-affected zone (HAZ). Furthermore, the EDM finishing process takes a longer time than the roughness process. In contrast, a newly developed machining process, based on conventional EDM, is proposed in order to overcome the preceding concerns and to satisfy the criteria of precise machining. In addition, this improved process for machining MMC materials is considered to be among the most essential methods in manufacturing industries (Ogata & Mukoyama, 1991).

According to literature review we concluded that EDM is a best approach for machining MMCs. The aim of this paper is to study the machining of MMCs by EDM and its variant. The machining of wide range of MMCs by EDM and its variant has been summarized in this paper. Lee and Zhang (1998) investigated the surface integrity of electro-discharge machined engineering ceramics as well as their surface modification by abrasive blasting. Hsu (1998) reported abrasive flow machining, which was an effective technique for improving the precision of the properties of the surface and shape of a small hole of a Ti–6Al–4V alloy fabricated by EDM.

2. Machining of MMCs by EDM and its Variants

2.1 EDM

EDM is an electro-thermal, non-conventional 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. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive (Saini et al., 2012). EDM system consists of four basic components tool electrode and work piece, pulsed power supply system, dielectric supply system and electrode feeding system which are shown in Fig. 1 (Shrivastava & Dubey, 2014). In EDM the electrode is moved downward toward the work material until the spark gap (the nearest distance between both electrodes) small enough so that the impressed voltage is great enough to ionize the dielectric (Bojorquez et al., 2002). EDM does not make direct contact between the electrode and the work piece where it can eliminate mechanical stresses chatter and vibration problems during machining (Singh et al., 2004).

EDM is a controlled metal-removal process that is used to remove metal 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. The metal-removal process is performed by applying a pulsating (ON/OFF) electrical charge of high-frequency current through the electrode to the workpiece. This removes (erodes) very tiny pieces of metal from the workpiece at a controlled rate.

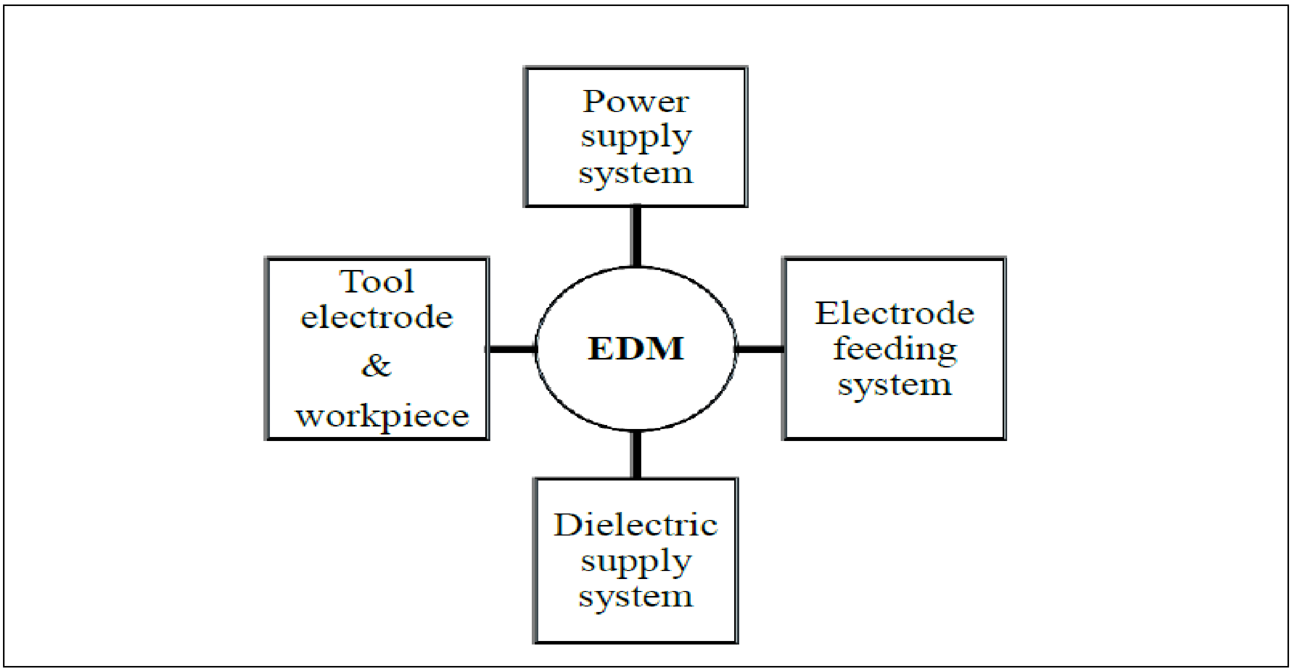


Fig. 1. Basic component of EDM

Electrical Discharge occurs at higher frequencies since the MRR for each discharge is very less change in weight. The material erosion mechanism primarily makes use of electrical energy and turns it into thermal energy through a series of discrete electrical discharges occurring between the electrode and work piece immersed in a dielectric liquid medium **(**Tsai et al., 2003)**.** The thermal energy generates a channel of plasma between the cathode and anode at a temperature in the range of 8000 to 12,000 °C **(**Boothroyd & Winston, 1989)**.** When the pulsating direct current supply occurring at the rate of approximately 15,000–30,000 Hz is turned off, the plasma channel breaks down. This causes a sudden reduction in the temperature allowing the circulating dielectric fluid to implore the plasma channel and flush the molten material from the pole surfaces in the form of microscopic debris. Gopalakannan et al. (2012) examined EDM of aluminium 7075 reinforced with 10 wt. % of B4C particles MMC (prepared by stir casting method). ANOVA was applied to investigate the influence of process parameters (pulse current, gap voltage, T_{ON} and pulse $T_{OFF)}$ on MRR, EWR and SR. It was found that pulse current and T_{ON} are significant factor that affect MRR and also foe EWR and SR. Caiazzo et al. (2015) performed EDM of René 108 DS nickel super alloy (aerospace turbine blades). The effects of discharge voltage, discharge current, duty cycle and reversion of polarity on MRR, TWR and SR were studied. It was concluded that in order to reduce the wear ratio when processing René 108 DS, the tool is suggested to be made anode.

2.1.1 Parameters of EDM

Parameters of EDM can be broadly classified into two categories i.e. process parameters and response parameters. Process parameters referred as input independent variable parameter (electrical and non-electrical) while response parameter includes depend variables. The various parameters of EDM are shown in Fig. 2.

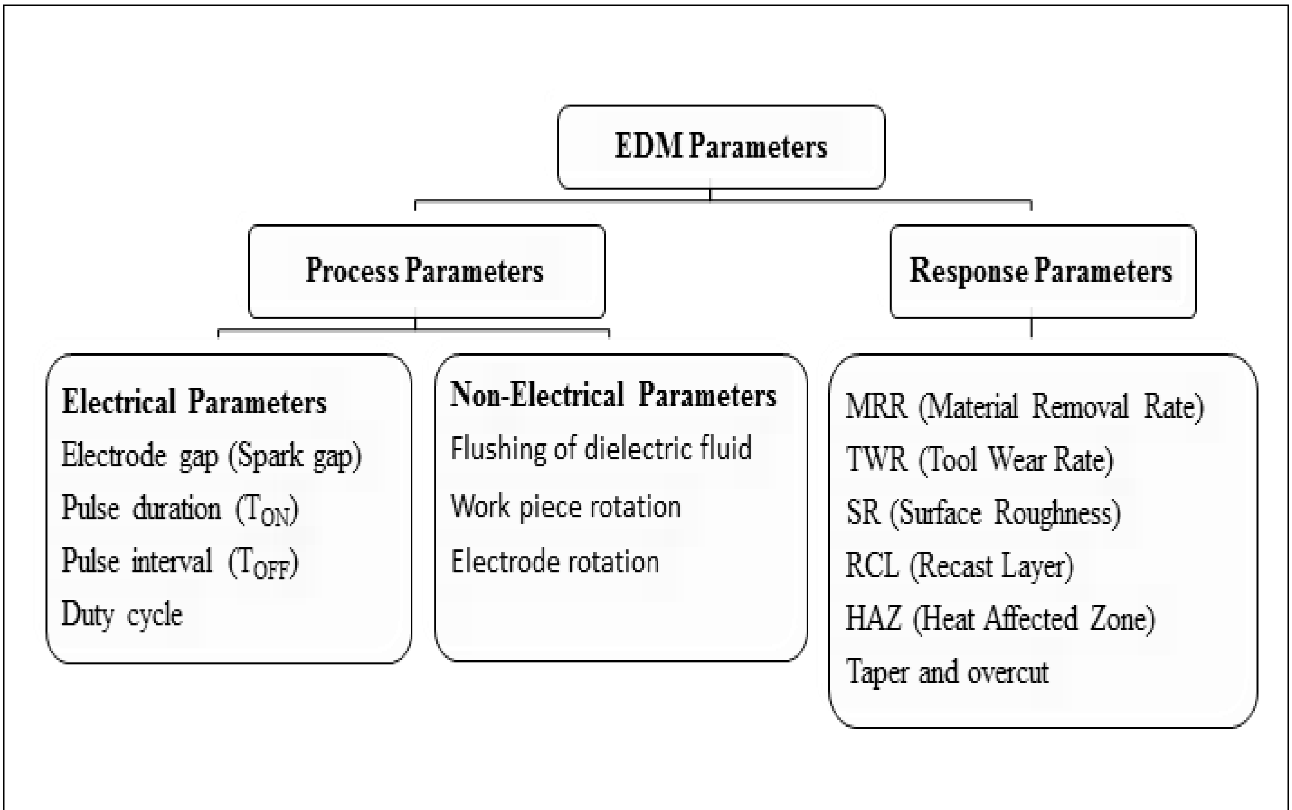


Fig. 2. Parameters of EDM (Shrivastava and Dubey, 2014)

2.1.1.1 Process parameters

(A) Electrical parameters

(i) Electrode gap (spark gap)

The distance between the electrode and the part during the process of EDM is known as electrode gap. An electro-mechanical and hydraulic systems are used to respond to average gap voltage. To obtain good performance and gap stability a suitable gap should be maintained. For the reaction speed, it must obtain a high speed so that it can respond to short circuits or even open gap circuits. Gap width is not measured directly, but can be inferred from the average gap.

(ii) Pulse duration (T_{ON})

It is the duration of time measured in micro seconds. Pulse duration is also known as pulse on time and the sparks are generated at certain frequency. MRR depends on longer or shorter pulse on time period. Longer pulse duration improves removal rate of debris from the machined area which also effects on the wear behaviour of electrode. Metal removal is directly proportional to the amount of energy applied during the on time period**.** The resulting crater produced will be broader as comparison to the shorter pulse on time. But in some experimental research work it has been proved that optimal pulse duration gives higher performance measures **(**Mohan et al., 2004)**.** At constant current and constant duty factor, the MRR is decreased with increase in pulse on time (Rao et al., 2008)**.**

(iii) Pulse interval (T_{OFF})

It is the duration of time in which no machining takes place (idle time period) and it allows the melt material to vaporize and to remove from setting. If the off-time is too short, it improves MRR but it will because more sparks to be unstable in the machining zone. Kansal et al. (2007) result out that increase in pulse interval time decreases the MRR. This parameter is to affect the speed and the stability of the cut. Saha et al. (2009) reported out that for small value of pulse interval time period, the MRR was low, but with further increase MRR increases. MRR was dropped slowly with increase in pulse interval time. Pulse wave form of pulse generator is shown in Fig. 3.

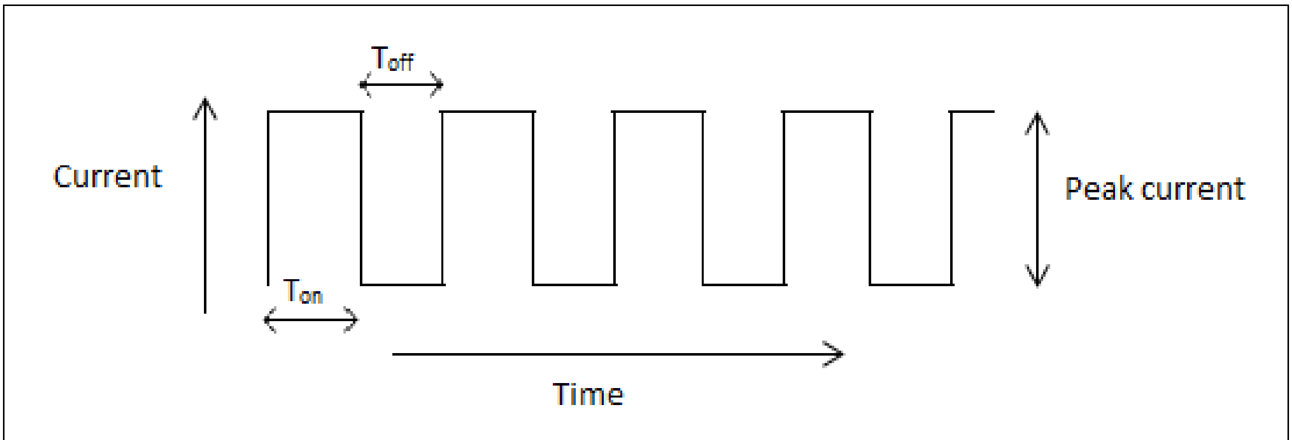


Fig. 3. Pulse wave form of pulse generator

(iv) Duty cycle

It is a percentage of the on-time relative to the total cycle time. This parameter is calculated by dividing the on-time with the total cycle time (on-time plus off-time) and it indicates the degree of efficiency of the operation. Amorim et al. (2002) find out the effect of duty cycle on the machining of AMP-8000. The researchers concluded that increase of duty factor increases MRR. This is due to the reason that with increase of duty cycle a black layer was seen on the surface of work material and with further more increase of it, the machining becomes unstable.

$$\text{Duty cycle } \equiv \frac{T_{ON}}{T_{ON} + T_{OFF}}$$

MRR increases with duty cycle this is due to the reason that with increase in duty cycle, the intensity of sparks increases resulting in higher MRR. Increase in duty factor at constant current constant pulse on (Rao et al., 2008)**.**

(B) Non electrical parameters

Main non-electrical parameters are flushing of dielectric fluid, workpiece rotation, and electrode rotation. These non-electrical parameters play a critical role in optimizing performance measures. Researches on flushing pressure reveals that it affects the SR, TWR, act as coolant and also play a vital role in flushing away the debris from the machining gap. Lonardo and Bruzzone (1999) reported that flushing pressure during the roughing operation affects the MRR and TWR while in the finishing operation, it influences the SR. Both MRR and TWR increased with increase in flushing pressure. The flushing pressure also influences the crack density and recast layer, which can be minimized by obtaining an optimal flushing rate based on empirical data. Workpiece rotary motion improves the circulation of the dielectric fluid in the spark gap and temperature distribution of the workpiece yielding better MRR and SR. Similarly, electrode rotation results in better flushing action and sparking efficiency. Hence, improvement in MRR and SR has been reported due to effective gap flushing due to electrode rotation (Guu & Hocheng, 2001, Yan et al., 2000).

2.1.1.2 Response parameters/performance measures

In EDM process important performance measures are MRR, TWR, and SR. In case of MRR work focused on material removal mechanism and methods of improving MRR (Rao et al., 2008)**.** Similar research work on tool wear process and methods of reduction in TWR has been reported (Mohri et al., 1995). Higher MRR during the machining results in improved economy of the industry. In this discussion machining was carried-out on the MMC (cylindrical specimen) with three reinforcement percentages by varying machining parameters to study the effect on MRR. Applied current has highest influence on the MRR. It was observed that MRR increases with increasing current. Similar trend was observed for other compositions of the MMC (Marigoudar & Sadashivappa, 2013). MRR also increases with increase in pulse on time. Pulse on time is the duration of time the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during pulse on-time. This energy is really controlled by the peak current and the length of the pulse on-time. The increase in the volume fraction of SiC in MMC causes reduction in the MRR. If the time gap between the pulses is short then material removal increases (Ahmad et al., 2010). Increasing bed speed against wire increases wire shifting marks or feed marks on the machined surface. These marks on the machined surface led to increase in surface roughness (Tosun, 2003).

2.2 Wire electric discharge machining (WEDM)

WEDM process is a special form of the traditional EDM process in which a continuously moving thin copper wire (0.05–0.25 mm diameter) performs as the electrode. The material removal mechanism is achieved by the melting and evaporation of workpiece material at each electrical discharge spot which are then ejected and flushed away by the dielectric fluid (Prohaszka et al., 1997). Material is eroded from the work material by a series of discrete sparks occurring between the work piece and the wire separated by a stream of dielectric fluid (Puri & Bhattacharyya, 2003). The wire is guided by sapphire or diamond guide and kept straight by a high value of wire tension, which is important to avoid tapering of the cut surface (Saha et al., 2005). In addition, the electrode does not contact with the work piece during the WEDM process. The schematic representation of Wire EDM process is shown in Fig. 4 (Groover, 2010).

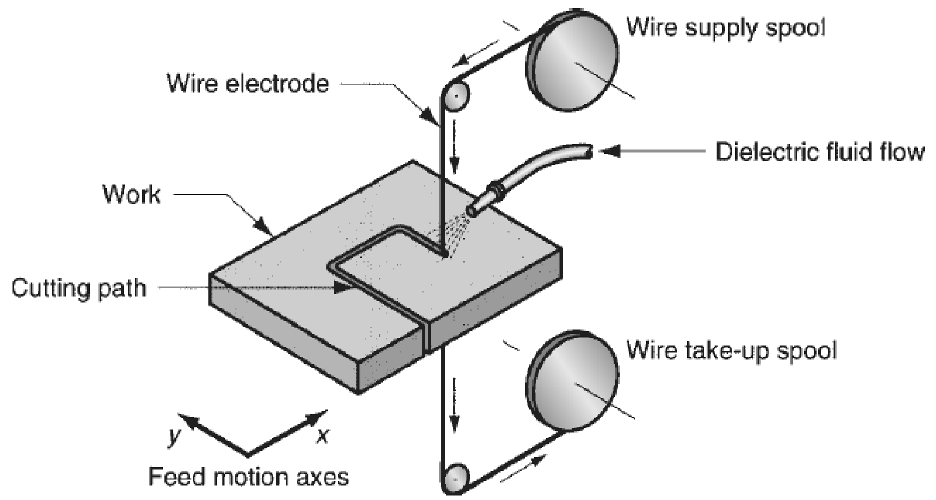


Fig. 4. Schematic diagram of Wire EDM process

Gatto and Luliano (1997) conducted WEDM tests under one roughing and two finishing conditions on two composites SiC 2009Al alloy with 15 % whiskers and with 20% particles reinforcement and surfaces scanning electron microscopy was used to examine machined surface It was observed that the WEDM rates (mm/min) was equal for both the composite. Roughness value of both composite obtained after performing WEDM test is shown in Fig. 5. Ali (2006) investigated on the effect and optimization of machining parameters on the MRR and SR in the WEDM process of Al-Cu-TiC-Si P/M composite. The settings of machining parameters were determined by using Taguchi experimental design method. The variation of MRR & SR with machining parameters is mathematically modeled by using non-linear regression analysis method.

The optimal machining parameters for the objective of maximizing MRR and minimizing surface roughness are performed.

Rozenek et al. (2001) examined the of machining parameters such as discharge current, T_{ON}, T_{OFF}, voltage on the machining feed rate and SR. WED machining was conducted on AlSi7Mg/SiC and AlSi7Mg/Al_2O_3 metal matrix composite. It was observed that the machining feed rate of WEDM cutting composites significantly depends on the kind of reinforcement. The maximum cutting speed of AlSi7Mg/SiC and AlSi7Mg/Al_2O_3 composites are found approximately 3 times and 6.5 times lower than that of cutting speed of aluminium alloy, respectively. Yan et al. (2005) performed WEDM of Al2O_3p/6061Al composite. It was concluded that the cutting speed, the surface roughness and the width of slit of cutting test material significantly depend on volume fraction of reinforcement (Al_2O_3 particles). Sarkar et al. (2006) examined the WEDM of γ titanium aluminide. They also tried to develop an appropriate machining planning for a maximum process yield criteria. A feed forward back propagation neural network was used to model the machining process. The three most important parameters the cutting speed, SR, and wire offset- have been considered as measures of the process performance. The effect of six different control parameters, i.e. T_{ON}, T_{OFF}, peak current, wire tension, dielectric flow rate and servo reference voltage on response parameters were studied. Shandilya et al. (2010) concluded that to achieve higher value of the average cutting speed, lower value of voltage and higher value of pulse-off time should be used during WEDC of SiCp/6061 Al MMC. Shandilya et al. (2011) investigated the effect of input process parameters such as servo voltage, T_{ON}, T_{OFF} and wire feed rate on MRR and kerf during WED machining of SiCp/Aluminum 6061 MMC. Response surface methodology (RSM) was used to analyse the experiments. The results obtained from experiment using analysis of variance (ANOVA) shows that voltage is the most significant parameter on MRR and kerf whereas T_{OFF} and wire feed rate are less significant. T_{ON} has insignificant effect on MRR and kerf.

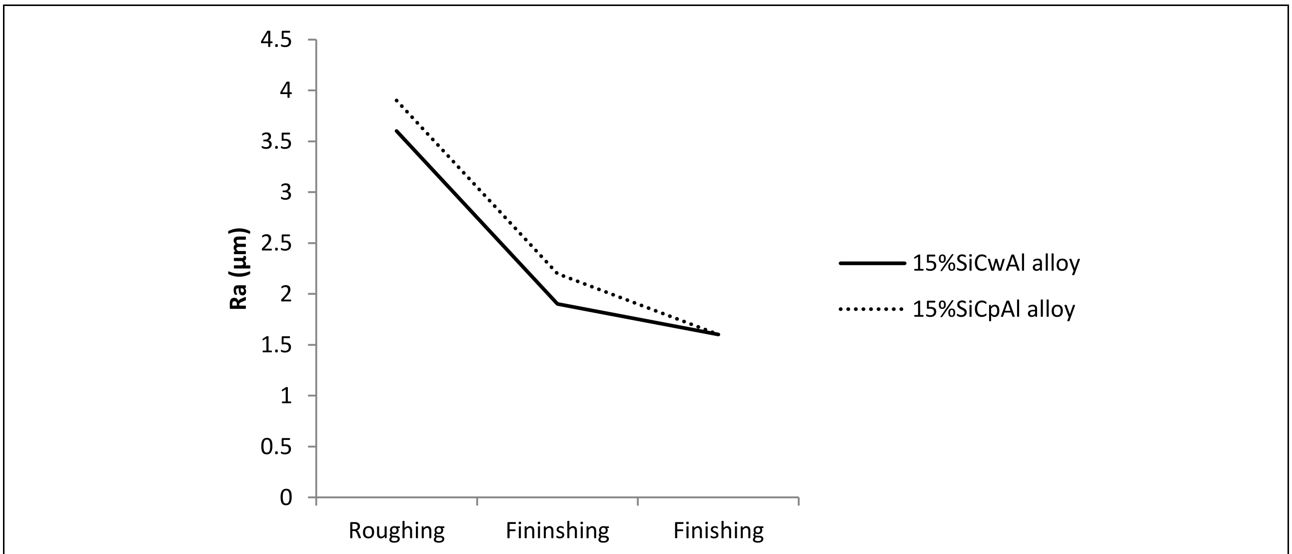


Fig. 5. Roughness value of WED-machined surface under one roughing and two finishing condition

2.3 Rotating disk electrode (RDE)-EDM

RDE is a typical method of EDM which develops in recent years. RDE-EDM is one of the variant process of EDM process based on removing unwanted material in the form of debris from a part by means of a series of recurring electrical discharges (created by electric pulse generators in microseconds) between a rotary tool called disc (thickness ranging from micron level to 1 mm) and the work material in the presence of a dielectric fluid (kerosene, distilled water). This fluid makes it possible to flush eroded particles from the gap (Pandey & Singh, 2010). In recent years the studying of micro electro mechanical Systems (MEMS) have resulted in the manufacture of small size products such as micro-pumps, micro-engines and micro-robots that have been successfully used in industrial applications. The technique of precision machining for such small devices has become increasingly important (Belhardj et al., 2003)**.** This new application of RDE-EDM machining is achieved by locating the rotating disk Electrode above or below the work piece to improve the debris removal rate. Chow et al**.** (1999) used rotary electrode in a modified conventional electrical discharge machine for micro slitting of work piece. High MRR was found due to superior debris disposal effect of RDE.

Yan et al**.** (2000) optimized the cutting of Al_2O_3/6061Al composite using rotary electrical discharge machining with a disk like electrode with Taguchi methodology. Taguchi methodology revealed that in general electrical parameters (Peak Current, Pulse duration and Gap voltage) affect the machining characteristics (MRR, electrode wear rate & SR) more significantly than the non-electrical parameters (speed of rotational disc). High MRR was found due to superior debris disposal effect of RDE. Yan et al. (1999) optimizes the blind-hole drilling of Al_2O_3/6061Al composite using rotary electro discharging machining by using Taguchi methodology. Increase of rotational speed of the electrode or the injection flushing pressure of the dielectric fluid result in a higher MRR. Mohan et al. (2004) investigated the machining characteristics of SiC/6025 Al composite using rotary EDM with a Brass tube electrode. Increase in volume percentage of SiC resulted in decrease in MRR and increase in EWR. The pulse duration had an inverse effect with MRR, electrode wear rate (EWR) and SR. The decrease in the hole diameter and increase in speed of the rotating tube electrode resulted increase in MRR and decrease in EWR and SR. In comparison, the electrode hole diameter and rotational speed have major effect on MRR, EWR and SR. The optimum machining parameter for maximum MRR, minimum EWR and better surface roughness were found out using genetic algorithm.

2.4. Dry EDM

In Dry EDM liquid is replaced by gas as the dielectric fluid (Kunleda et al., 2003). Through a pipe electrode the gas is supplied to the discharge gap in order to eject debris particles from the gap and cool the discharge spot and electrodes. Dry EDM is characterized by small tool electrode wear, negligible damage generated on the machined surface. When oxygen gas is used MRR is high due to oxidation of the work piece. However, the narrow discharge gap length compared with conventional EDM using oil as the dielectric working fluid results in frequent unstable machining due to the occurrence of short circuiting which lowers MRR. To control the gap length of the

EDM machine, a piezoelectric actuator with high frequency response was introduced. To achieve maximum MRR with low tool EWR, a dry EDM simulator was developed which can evaluate the machining stability and material removal rate of dry EDM (Kunieda et al., 2004). The technique was developed to decrease the pollution caused by the use of liquid dielectric which leads to production of vapour during machining and the cost to manage the waste (Pandey & Singh, 2010). Kunieda et al. (1991) concluded that by introducing oxygen gas into the discharge gap increases the material removal rate in water as a dielectric medium. Dry EDM with air as the dielectric is feasible with reverse polarity (Saha et al., 2009). Tao et al. (2008) concluded that by combining oxygen gas with copper tool gives high MRR in dry EDM.

2.5 Die sinking EDM

Sinker EDM also called cavity type EDM or volume EDM consists of an electrode and workpiece submerged in an insulating liquid such as, more typically oil or less frequently other dielectric fluids. The electrode and workpiece are connected to a suitable power supply. The power supply generates an electrical potential between the two parts. As the electrode approaches the workpiece, dielectric breakdown occurs in the fluid, forming a plasma channel and a small spark jumps. These sparks usually strike one at a time because it is very unlikely that different locations in the inter-electrode space have the identical local electrical characteristics which would enable a spark to occur simultaneously in all such locations. These sparks happen in huge numbers at seemingly random locations between the electrode and the workpiece. As the base metal is eroded and the spark gap subsequently increased, the electrode is lowered automatically by the machine so that the process can continue uninterrupted. Several hundred or thousand sparks occur per second, with the actual duty cycle carefully controlled by the setup parameters. These controlling cycles are sometimes known as T_{ON} and T_{OFF}.

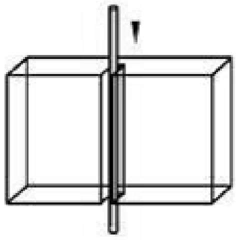
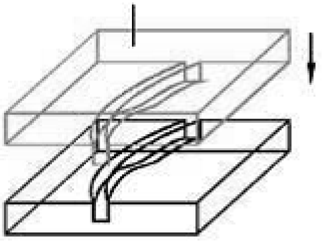
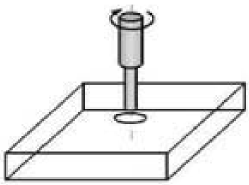
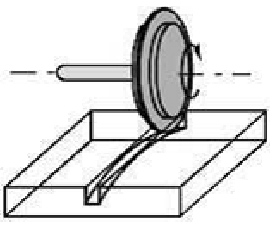
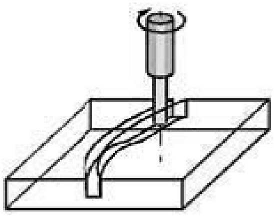
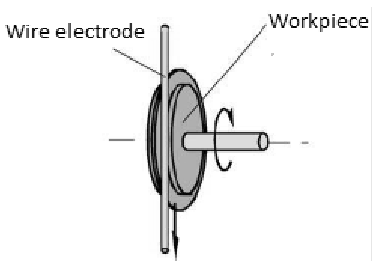
The T_{ON} setting determines the length or duration of the spark. Hence, a longer on time produces a deeper cavity for that spark and all subsequent sparks for that cycle, creating a rougher finish on the workpiece. The reverse is true for a shorter on time. T_{OFF} is the period of time that one spark is replaced by another. A longer off time for example allows the flushing of dielectric fluid through a nozzle to clean out the eroded debris, thereby avoiding a short circuit. These settings can be maintained in microseconds. The typical part geometry is a complex 3D shape, often with small or odd shaped angles. Vertical, orbital, vectorial, directional, helical, conical, rotational, spin and indexing machining cycles are also used (Pandey & Singh, 2010).

Ramulu and Taya (1989) investigated machinability of 15 vol. % and 25 vol. % SiC whisker/2124 aluminum matrix (SiCw/Al) composites. The material samples were cut at coarse, medium, and fine conditions using copper and brass tools. It was found that MRR increases with increase in power of electrode. MRR in 15 vol. % SiCw/2124 Al is found more than 25 vol.% SiCw/2124 Al. MRR obtained by using copper electrode is 5-10% less than that of obtained when using brass electrode. Singh et al. (2008) in the same year worked on Al-10% SiCp as cast MMCs. The objective of the work was to investigate the effect of current, TON and flushing pressure on MRR, TWR, taper, radial overcut, and SR of machined material. It was observed that MRR was found higher for larger current and TON settings at the expense of taper, radial overcut, and surface finish. EWR was also found to be higher, even larger than the MRR for larger current settings. The dimensional accuracy is affected at higher current and TON ratings. Both MRR and EWR are considerably influenced by flushing pressure. Singh et al. (2008) have carried out a comparative machinability study on stir-casted 6061Al/Al2O3P/20p work specimens by using plain dielectric and silicon carbide abrasive powder-suspended dielectric fluid. Copper electrode was used for experimentation. They evaluated machinability in terms of surface roughness. The results of both the processes have been analyzed using Lenth's method to find the significant parameters and to obtain optimum machining parameter settings. It was found experimentally, that abrasive particle size, abrasive particle concentration and pulse current are the most significant parameters that affect the surface characteristics.

2.6 Micro EDM

According to CIRP committee of Physical and Chemical processes, the term micro-machining defines the processes that manufacture products in the range of 1 to 999 µm (Masuzawa & Tonshoff, 1997). The term 'micro' was used to present the miniaturization of electronic components and devices. However, with the present trend in the miniaturization of mechanical components, it is also being applied for the generation of microscopic mechanical components and devices. The system has a servo system with highest sensitivity and positional accuracy of + 0.5 µm. In order to reduce the size of product micro EDM was developed and the basic physical characteristics of the micro-EDM process is essentially similar to that of the conventional EDM process with the main difference being in the size of the tool (electrode) used, the power supply of current and voltage supply, and the resolution of the X-, Y- and Z- axes movement. It permits setting of a minimized discharge gap width of 1µm (Pandey & Singh, 2010). Therefore, the system is helpful for conventional precision engineering purposes as well as for micro components fabrication like micro-molds, micro inserts, and in general filigree structure up to 5 µm (Koch et al., 2001). The process variants of micro EDM are µ-WEDM (micro Wire EDM), µ-ED drilling (micro electric discharge drilling), µ-ED milling (micro electric discharge milling), µ-EDG (micro electric discharge grinding), µ-WEDG (micro wire electric discharge grinding). The process varaint of micro-EDM are given in Table 1.

Zhao et al. (2010) machined SiCp/Al using micro EDM. Firstly a micro tool electrode of Φ 40 µm × 4.1 mm with the aspect ratio up to 100 was made and then through experiments the effect of open-circuit voltage and electrode material on processing speed and electrode wear was studied. Finally 28 µm wide micro slits, micro square platform of 34µm long on each side and other micro three-dimensional structure were machined. It was concluded from experiments 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 composite.

S.No.	Process	Schematic representation	Surface quality Ra (mm)	Application
1	Micro-wire EDM (μ-WEDM)		0.1–0.2	-Forming tools for opto-electronic components, -Lead frame stamping tools, -Spinning nozzles -Micro gears,
2	Micro-die sinking (μ-die sinking)		0.05–0.3	-Micro injection moulds -Embossing moulds for micro-optics
3	Micro electrical discharge drilling (μ-ED drilling)		0.05–0.3	-Injection nozzles -Micro-fluid systems -Starting holes for μ-WEDM
4	Micro-electrical discharge grinding (μ-EDG)		-	-Embossing and coining tools - Micro fluid Channels
5	Micro-electrical milling (μ-ED milling)		0.5–1	-Cavities for micro injection moulding – Embossing or coining tools
6	Micro-wire electrical discharge grinding (μ-WEDG)		0.8	-Pin electrodes -Rolling tools

Tab. 1. Micro EDM variants and its characteristics (Uhlmann et al., 2010; Jahan et al., 2011)

Muller et al. (2000) studied the capability of machining SiC particle-reinforced aluminium matrix composites using EDM method. The low MRR was found for composite due to the poor electrical conductivity of SiC particles.

Compared to the above methods, the mechanical micro-machining process is promising to mass produce MMCs parts. This approach is cost-effective, flexible, and controllable, precise (relative accuracy as 10^{-3} to 10^{-5}) and capable to make arbitrary 3D pattern. Using micro-machining technique, small components can be manufactured more efficiently with lower cost and higher quality.

3. Summary

This review paper is focused on machining of MMC (difficult to machine by conventional machining process) by different variants of EDM. The review has been carried out in all aspects and variants of EDM process such as die-sinking EDM, wire EDM and micro EDM etc. MMCs have found many successful industrial applications in recent past as high-technology materials due to their properties such as high strength-to-weight ratio, high toughness, lower value of coefficient of thermal expansion, good wear resistance, and capability of operating at elevated temperatures. The EDM process is suitable for machining MMC however the process is relatively slow.

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