A REVIEW ON CNC WIRE CUT ELECTRICAL DISCHARGE MACHINING (WEDM) OF METAL MATRIX COMPOSITE

Chintan Avichal¹, Milan Patel² and Dr. Piyush Jain³

¹P.G. Student, Department of Mechanical Engineering, SNPIT&RC, Umrakh, Bardoli
²Assistance Professor, Department of Mechanical Engineering, SNPIT&RC, Umrakh, Bardoli
³Associate Professor, Department of Mechanical Engineering, SNPIT&RC, Umrakh, Bardoli

Abstract—These research deals with increasing demands for higher surface finish, machining of complex shape geometries and higher material removal rate, conventional machining process are now being replaced by non-traditional machining processes. Wire-electrical discharge machining (WEDM) is widely accepted for machining complex and intricate shape for conductive material which are difficult to be machined by other main stream machining process. This could be achieved with high degree of dimensional accuracy and surface finish. This paper reviews the comprehensive study of Wire EDM process parameters, performance measures and its application. This review paper are based on the notable research work done by various researchers in the field of wire electrical discharge machining of MMCs.

Index Terms—Metal matrix composite, material removal rate, surface roughness, Wire EDM.

I. INTRODUCTION

Metal matrix composite (MMC) material plays a vital role in the modern industrial sector, engineering in response to unprecedented demands from technology due to rapidly advancing activities in aircrafts, aerospace and automotive industries. They possess superior mechanical and physical properties such as high strength to weight ratios, stiffness to weight ratio, low coefficient of thermal expansion, better wear resistance and low density is major properties that are applicable in aerospace, military and automotive sector. The ceramic reinforcement in the form of particulates, whiskers to improve the strength, stiffness, thermal conductivity and dimensional stability and also operate at elevated temperature. The traditional methods such as broaching, milling, grinding are difficult to produce complex shape in such materials. High tool wear and tooling cost may be occurred while using traditional machining method to machined metal matrix composites. Therefore non-traditional machining process such as electrochemical machining process, plasma cutting, laser cutting and water jet cutting to machine these metal matrix composite but these processes have limited to linear cut only. Wire electrical discharge machine (WEDM) is a special form of the non-traditional EDM that can be successfully employed to machine electrically conductive parts irrespective of their hardness, shape and toughness. Wire cut EDM (WEDM) is a widely accepted non-traditional material removal process used to manufacture components with intricate shapes and profiles irrespective of hardness. This process is extensively in tool and die-making industries, automotive industries and aerospace industries. WEDM has been defined as the process of material removal of electrically conductive materials using thermo-electric source of energy.in WEDM process continuously moving conductive wire electrode to produce complex two or three dimensional shapes in electrically conductive work piece using the EDM process. The material removal is by controlled erosion through a series of repetitive sparks between the workpiece and wire electrode in the presence of dielectric fluid. The gap between the wire and work piece is flooded with a stream of dielectric fluid which is directed or continuously fed to a working zone by a series of nozzle. In these WEDM process the electric energy turns in to thermal energy through a series of electric spark to remove the material from workpiece. This generates a plasma channel during the pulse on time and raises the temperature as high as 20,000°C, which initializes the melting and evaporation of both work piece and wire electrode. When the pulse is turned off, plasma channel breaks down and
circulating dielectric fluid flushes out molten material in the form of microscopic debris. This action is repeated hundreds of thousands times each second during WEDM processing. This removes material from the work piece in shape opposite of the wire. As the material removal per discharge is very small, discharges should occur at high frequencies (103-106Hz). For every pulse, discharge occurs at a single location. As a result a small crater is generated both on the wire electrode and work piece surface. Dielectric system is the subsystem of the wire EDM in which deionized water is used because of its low viscosity, higher cooling rate, higher material removal rate, no fire hazard in these system. Therefore, wire EDM is a non-conventional process and is very widely used in tool steels for pattern and die making industries. The process is also used for cutting intricate shapes in components used for the electric and aerospace industries.

![Schematic representation of WEDM Process](image)

II. LITERATURE REVIEW

This chapter include the brief literature on wire-cut electro-discharge machining of Metal matrix composites.

D. Satishkumar et. al.[1] studied the effect on wire cut electro-discharge machining process parameter of Al6063/Sic metal matrix composite in various volume fraction 5%, 10%, and 15% of silicon carbide (Sic) prepared through stir-casting process. The experiments are carried out as per design of experiments approach using L9 orthogonal array. The results were analyzed using analysis of variance and response graphs. The results are also compared with the results obtained for unreinforced Al6063. They found that increase in volume fraction of reinforcement particle (Sic), the material removal rate (MRR) decreases and surface roughness (Rₐ) increases. They also concluded that the hardness of the composite also varied in the range of in the range of 96-111 HBW affected by volume fraction of Sic particle. The gap voltage is most significant factor on MRR. They also compare the experimental value and predicted value based on L9 orthogonal array for material removal rate (MRR) and surface roughness (Rₐ).

Rajaneesh N. Marigoudar et. al.[2] investigate the effect of machining parameter on material removal rate (MRR) and surface roughness (Rₐ) during machining of zinc-aluminium alloy reinforced with silicon carbide particle (ZA43/Sic) MMC fabricated by liquid metallurgical technique. In this research paper silicon carbide particle with 5%, 10%, 15% by weight. Non consumable molybdenum wire of 0.18 mm diameter are used for machining. Scanning electron microscope technique are used to confirm that the Sic particle are uniformly distributed in matrix material. In these machining process by varying applied current of (2, 4 and 6amp.), pulse on time (4, 8 and 16μs) and pulse off time (5, 7 and 9μs) whereas the other parameters such as voltage, dielectric flushing pressure, wire tension etc. are maintained constant. They have concluded that Material removal rate increases with increase in current and pulse on time and its decreases with increase in pulse off time. Material removal rate also decreases with increases as reinforcement particles. Surface roughness increases with increase in peak current.

Nilesh G. Patil et. al.[3] carried out to investigate the effect of electrical and non-electrical parameter on the performance characteristics for machining on Al/Al₂O₃ metal matrix composites. These MMC with 10% and 20% reinforced particle are used. In these research paper zinc coated brass wire are used as cutting tool. Based on taguchi L27 orthogonal array method to optimize the process parameter such as pulse on time, pulse of time, peak current to achieve the maximum material removal rate and minimum surface roughness. The conclusion of these research paper is that the increase the volume fraction of ceramic reinforcement which results in decrease the cutting speed. The surface finish of MMC was found
to deteriorate with increased volume fraction of Al$_2$O$_3$ reinforcements. Wire breakages of CNC wire EDM is also be reduced by using higher flushing pressures, appropriate pulse off-times, and suitable value of servo reference voltage.

Pragya Shandilya et.al.[4] These paper have studied to predict the average cutting speed while WEDM of Al6061/Sic MMC based on response surface methodology (RSM) and artificial neural network (ANN) through box-behnken design. A diffused brass wire of 0.25 mm diameter is used as cutting tool. Deionized water is used as working medium between work piece and wire electrode. They have selected the four process parameter as input such as pulse on time ($T_{on}$), pulse off time ($T_{off}$), servo voltage (SV) and wire feed rate effect on average cutting speed. They concluded that prediction accuracy of ANN model is three times better than RSM. The input parameter voltage is more significant effect on average cutting speed than pulse off time and wire feed rate during WEDM.

Uday A. Dabade et. al.[5] discussed the multi-objective optimization using Taguchi based GRA to improve the surface integrity on turned surface of Al/SiCp MMCs. Surface quality/integrity related parameters such as cutting forces, surface roughness, residual stresses and micro-hardness variation were selected as target responses. The optimum process parameters to improve the surface integrity on Al/SiCp composites were identified. Experiments on Al/SiCp composites of four different compositions are performed using L27 orthogonal array as per the Taguchi method. The GRA based best and worst machining conditions change with size and volume fraction of reinforcement in composites. The best optimized combination of machining conditions to enhance the surface quality/integrity on machined surfaces of Al/SiCp composite is use of 0.8 mm tool nose radius, wiper type insert geometry, 0.05 mm rev-1 feed rate, 40 m min-1 cutting speed and 0.2 mm depth of cut.

Sanjiv Kumar et. al.[6] investigate the process parameter in WEDM of WC-6%Co composite based on response surface methodology (RSM). In this experiment the effect of input parameters like pulse-on-time, pulse-off-time, voltage and current on output response parameter such as cutting speed and dimensional deviation have been studied. Brass wire of 0.25mm diameter is used as an wire electrode and de-ionized water is used as dielectric fluid. Wire tension and wire feed parameters were constant at 8m/min and 8 unit respectively and High flow rate results in quick and complete flushing of melted debris out of the spark gap. The conclusion of these research paper is that Cutting speed increases with increase in pulse on time and peak current (Ip) whereas peak current and pulse on time (Ton) have not much effect on dimensional deviation. Minimum value of servo voltage and pulse off time ($T_{off}$) is desirable for high cutting speed and vice versa for dimensional deviation.

G.Ramesh et. al.[7] studied the effect of input process parameter such as servo voltage, pulse on time, pulse off time, current on output parameter material removal rate and surface roughness while WEDM of Hybrid Aluminium (Al7075/Sic/B$_4$C) metal matrix composite. In these paper Al matrix is reinforced with composition variation of Sic and is 3%, 7% and B$_4$C is also 3%, 7% respectively. Optical microscope images shows composition of reinforcement particle in matrix. The hardness of Hybrid Aluminium MMC increases with the weight fraction of particulate in the alloy matrix. The conclusion of these research paper is that material removal rate decreases and surface roughness increases with the addition of reinforcement in composite materials.

Nilesh Ganpatrao Patil et. al.[8] carried out to determination of material removal rate (MRR) using the dimensional analysis when machining of metal matrix composite by WEDM. In these experiment researcher have to studied the Al matrix with reinforcement particle Sic with 10%, 20%, 30% and pulse on time, pulse off time, Average voltage are taken as input parameter and material removal can be determined. Brass wire (CuZn37) of 0.25mm diameter is used as a wire electrode and de-ionized water is used as dielectric fluid. Scanning electron microscope result shows that the composition of Sic present in the Al matrix. The conclusion of these research paper is that increase in percentage of ceramic particulate to decrease the material removal rate compared to 10% Sic particulate. Also, the coefficient of thermal
 expansion, thermal diffusivity and melting point temperature are significant parameters on MRR.

S Ramesh et al.[9] developed the Hybrid Aluminium metal matrix composite by stir casting technique using Al 6061 alloy as matrix and by varying the reinforcement particulates of Silicon carbide (Sic) and boron carbide (B4C) are added in the matrix material. Optical microscope technique are used to shows the presence of Sic and B4C. In these experiment the machining process parameter such as pulse on time, pulse off time, current and voltage are varied at three level are selected as input parameter on output parameter material removal rate (MRR) and surface roughness are predicted by fuzzy model using MATLAB software. The conclusion of these research paper is that the increase in percentage of reinforcement particulate leads to decreases the MRR and surface finish. By using the fuzzy model the MRR and Surface roughness with variation of 6.3% and 3.5% respectively from experiment value.

Sanjeev KR. Garg et al.[10] 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 condition for multi-objective optimization were pulse width: 1.14 s, time between pulses: 4.61 μs, short pulse time: 0.7 μs, servo control mean reference voltage: 50 volts, wire feed rate: 11.1 m/min and wire tension: 0.43. The value of performance measures obtained were: cutting velocity = 8.234 mm/ min and surface roughness = 1.803μm. The values of the performance measures proved that the newly developed MMC could be effectively machined by wire EDM.

Amitesh Goswami et al.[11] investigate the process parameter by using taguchi and grey relational analysis for machining of Nimonic 80A alloy. The effect of input parameter pulse on time and pulse off time on output parameter surface integrity, material removal rate and wire wear ratio have been studied. The Scanning electron microscope (SEM) technique is used to find the surface integrity and surface characteristics of machined surfaces. Electro dispersive spectrograph technique is also used to structure and compositional analysis. The conclusion of these research paper is that higher pulse-on time setting leads to thicker recast layer. Also, lower value of pulse-on time and higher value of pulse-off time, the wire deposition on the machined surface is low. Pulse on time and pulse off time have most significant effect on material removal rate.

Dr. A. Manna et al.[12] studied the effect of input parameter such as wire feed rate and tension in WEDM of Al6063/Sic MMC with 300 mesh size and 15% silicon carbide particle fabricated by stir casting technique. These stir casting technique is economical for production of metal matrix composite. Prepared composites are machined by 0.25 mm brass wire electrode with the help of deionized water. The deionized water work as a working medium between wire electrode and work piece. This paper present the varying feed rate and tension on the effect of cutting speed, width of the cut, MRR, surface roughness. The conclusion of this research paper is as maximum cutting speed and MRR are obtained with increase in wire feed rate and also improve surface finish.

Yan et al.[13] investigated the machining of Al2O3/6061 Al-composite on WEDM with the Reinforcement of 10 and 20 volume %. The machining performance was evaluated with pulse on time as machining parameter variable. The cutting speed is found to be highest for matrix alloy Al-6061 than the Al2O3p/6061 Al-alloy composites. Also both composites yielded similar cutting speed on WEDM. The increase in volume fraction of reinforcement
resulted in wire breakage. The machined surface of 10 volume % Al2O3p/6061 Al composite is smoother than that of 20 volume % Al2O3p/6061 Al-composite. The width of slit of cut for 20 volume %Al2O3/6061 Al-composite was found to be much narrower than that of the metal matrix 6061 Al-alloy and the 10 volume % Al2O3p/6061 Al-composite.

III. FUTURE SCOPE
The most of research work has been done on optimization on process parameters for improvement of a single quality characteristic such as material removal rate and surface roughness. In future multi optimization of process parameters on WEDM of MMC will thrust full area that can be study.

IV. CONCLUDING REMARK
After referring literature review, Wire-EDM is widely accepted non-traditional material removal process for machining and micro-machining part with intricate shapes and varying hardness requiring high accuracy. The response values of material removal rate and surface roughness are change by varying weight fraction of reinforcement in MMC and other input parameters pulse on time, pulse off time and peak current for machining of Metal matrix composites(MMC) in Wire-EDM. Multi-response optimization of WEDM process is another thrust area which leads engineers to investigate this study.

ACKNOWLEDGMENT
I would like to acknowledge and extend my sincere gratitude to Mr. Milan R. Patel and Mr. Akash B. Pandey for the constant support, valuable advice and help that they provided for preparing this paper.

REFERENCES
