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Fabrication of micro electrode array using WEDM

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***Abstract*---**Now days there are different technologies in machining processes. Among all those Wire Electric Discharge Machining (WIRE EDM) plays a key role in machining. Wire EDM is widely used in production, aerospace/aircraft, medical and virtually all areas of conducting materials. The main objective of this work is to fabricate different micro arrays and electrodes using micro WEDM process**.** Miniaturization has become a prime issue for modern manufacturing industries. The main advantage of miniaturization is reducing the production cost, time, material, volume and weight. This technique is used in various area like automobiles, aerospace, electronics, medical devices, etc. This miniaturization technique is mainly achieved by non-traditional machining processes and micro machining. Some of the non-traditional machining processes are water jet machining, abrasive jet machining, ultrasonic machining and wire electric discharge machining processes.

***Keywords*---**WEDM, technologies, miniaturization technique.

Introduction

During conventional machining processes an increase in hardness of work material results in a decrease in economic cutting speed. Production of complex shapes by traditional methods is more difficult. To meet higher requirements like better finish, low values of tolerances, higher production rates, complex shapes, automated data transmission, miniaturization etc. needs a different class of machining processes that is non-traditional machining processes or advanced machining processes have been developed. There is a need for machine tools and processes which can accurately and easily machine the most difficult-to- machine materials to intricate and accurate shapes. The machine tools should be easily adaptable for automation as well. In order to meet this challenge a number of newer material removal processes have now been developed to the level of commercial utilization. These newer methods are also called unconventional in the sense that conventional tools are not employed for metal cutting. Instead the energy in its direct form is used to remove the materials from the work piece. Weiliang zeng, et. al [1], compared working efficiency of using micro electrode array and single electrode array to machine micro hole array by micro EDM. It results that the micro electrode array gives more efficiency compared to single electrode array. New technology of large scale micro electrode array and micro hole array fabricated by combined micro EDM and EMM is proved to be feasible and high efficient. The average processing speed of single micro electrode perforated is 74μm/min and the average processing speed of micro electrode array perforated is 12μm/min, a difference of six times. But for perforating a single hole, the average processing speed of micro electrode array is 1200μm/min, is 16 times than that of a single electrode. And then, compared to single electrode processing, its discharge gap is in the state of short circuit and open circuit frequently, the processing efficiency of fabricating holes by micro electrode array is much higher. Venugopal T R, et. al.[2], discussed Machining of microelectrodes with non-circular cross- section is a difficult task. Few methods were recently reported in the literature but they are very complex and expensive. This paper proposes to develop a simple technique for grinding differently shaped tool electrodes for micro-EDM. Trial experiments were carried out to fabricate square and hexagonal shaped microelectrodes on graphite rod by mechanical grinding. Experimental results obtained showed that the developed in-situ tool grinding system with indexing mechanism is suitable for fabricating polygonal shaped tool electrodes for die-sinking micro-EDM. Dain Thomas et. al.[3], used response surface methodology(RSM) and conducted different experiments on process parameters like pulse on time, pulse off time, wire tension, peak current. He used zinc coated brass as wire and EN31 steel as work piece. This research paper mainly concentrated on metal removal rate and conducted several experiments on sprint cut WEDM machine and finally found that major influence on Metal removal rate(MRR) have been found to pulse on time and pulse off time. Mohd Shahir Kasim, et. al.[4] worked on improving the surface roughness using response surface methodology. This paper conducted several experiments by changing different parameters like servo voltage, wire feed rate and current on Mitsubishi RA90 series CNC WEDM. This results that best surface roughness of 2.797μm (horizontal) and 2.806μm (vertical) was achieved with the combination of servo voltage of 42v and, wire feed of 1.44mm/min and current of 6A. Baljit Singh et. al.[5] conducted different experiments on metal removal rate using taguchi approach. This paper mainly concentrates on peak current, pulse off time, servo voltage, wire feed rate, wire tension and pulse on time using ecocut CNC WEDM and found that best MRR was obtained when pulse on time is 120μs, pulse of time is 55μs, wire tension 1300g, servo voltage 80v, wire feed 15mm/min and current 6A. Kumar k. et. al.[6], worked on different process parameters like pulse on time, pulse off time, wire speed and wire feed by using Taguchi method and made some conclusions on surface roughness. In this paper, the main aim is to increase surface by using sprint cut 734 CNC WEDM with molybdenum wire and found that minimum surface roughness of 1.257μm achieved when Ton is 104 μs, Toff is 42μs and wire feed is 0.5mm/min. Nandakumar C, et. al.[7], conducted several experiments on surface roughness by changing the parameters like pulse on time, pulse off time, wire feed by using Taguchi L18 orthogonal array method. The wire was made of zinc coated brass and the work piece was titanium alloy grade 5. From this work, the minimum surface roughness of 1.8825μm was achieved when Ton is 5μs, Toff is 8μs wire tension (WT) is 1000g and wire feed (WF) is 3mm/min. Pratik A Patil, et. al.[8], worked on increasing the material removal rate(MRR) by using response surface methodology. They have taken grass wire and AISI 02 steel as work piece. The process parameters were pulse on time, peak current and wire tension. The final conclusions are, the MRR increases as the peak current increases as the peak current increases and the MRR is influenced by the wire tension and pulse on time. Shinde VD, et. al.[9], using electronic ELCUT CNC WIRE EDM, made several experiments in order to find the best surface roughness parameters like pulse on time, pulse of time, peak current and wire feed. The Taguchi approach gave best results on surface roughness. From this work, the main conclusion was that the wire speed and pulse on time shows strongest correlation to surface roughness as compared to current and pulse off time. Singh H and Garg R[10] found that MRR increases with increase in IP and Ton while decreases with increase in Toff and servo voltage. The work mainly concentrated on material removal rate and followed Taguchi approach. The process parameters considered were pulse on time, pulse off time, gap voltage, wire feed rate, wire tension and peak current. The wire used was brass and work piece was H-11 die steel. Subrahmanyam SV, et. al.[11], worked on surface roughness of ELPUL40A CNC WEDM using Taguchi L36 orthogonal array method. The process parameters considered were pulse on time, pulse off time, peak current, wire tension, wire feed, servo feed and fluid pressure. It was found that surface roughness of 2.48μm was obtained when Ton is 128μs, Toff is 53μs, wire feed is 4mm/min, servo voltage is 20v, wire tension is 2 kgs and IP is 230A. Basil Kuriachen, et. al.[12], worked on improving the performance parameter of surface roughness by considering different parameters like pulse on time, pulse off time, voltage and dielectric pressure by following mathematical model. After several experiments on electronica ultracut, it was found that minimum surface roughness is obtained when pulse on time 20μs and dielectric pressure is 15kfg/cm3. Prediction error was obtained using this model is 7%. Rajendran S and Marimuthu K[13]worked on improving the performance parameters of material removal rate using Response surface methodology. They used electronic sprintcut734 machine and considered different process parameters like pulse on time, pulse off time, peak current and wire tension. Conducting several experiments, it was found that pulse on time is directly proportional to the material removal rate whereas wire tension is inversely proportional to the material removal rate. Material removal rate was optimized at 0.5 for the optimum value of peak current (200A) and wire tension of 7.5g. Anish kumar, et al.[14], worked on improving the performances parameters of surface roughness using response surface methodology. They considered pulse off time, peak current, pulse on time, wire feed and wire tension. Using electronica super cut 734 WEDM and found that surface roughness of 2.48μm is obtained when pulse on time is 112μs, pulse off time is 56μs, wire feed is 7m/min, servo voltage is 60v, wire tension is 980grams and peak current is 120A. Sivakiran S, et. al[15], worked on Omnicut CNC WEDM for the improvement of material removal rate by changing different process parameters like pulse on time, pulse of time,bed speed and current. Different experiments were conducted using Taguchi's L16 approach with Molybdenum wire and work piece as EN31 steel. It was found that best MRR was observed when pulse on time is 24µs, pulse of time is 6µs, and current is 5A. Abdulkareem S, et al.[16], worked on improving the surface roughness using full factorial design method. They conducted several experiments by changing different process parameters like pulse on time, pulse current and gap voltage using Mitsubishi WEDM. After conducting several experiments, two results were found. They are, wet wire EDM gives better surface integrity compares to dry wire EDM and also the increase of pulse current and gap voltage also contributes poor surface integrity. Islam MN, et al.[17], conducted several experiments on dimensional accuracy by changing different process parameters like pulse on time, wire speed, wire tension, and flow rate. In this paper, Fanuc Robocut machine was used and the method followed was Taguchi L27 orthogonal array method, wire used was brass and mild steel 1040 as work piece. Finally, after conducting several experiments it was found that, wire tension is the greatest affecting parameter on dimensional accuracy characteristics like linear error, flatness error and perpendicularity error. Alpesh M Patel and Vishal Achwal[18] worked on improving the performance parameters like electrode wear rate and material removal rate using electronica 5535R50 ZNC series CNC WEDM with brass wire and aluminium A1050A as work piece. The parameters taken into consideration were discharge voltage, wire feed, wire tension and discharge current. The methodology applied was Taguchi's L9 orthogonal approach and found that maximum MRR of 0.041gm/min and minimum electrode wear rate (EWR) was obtained when voltage is 35v, wire feed is 6mm/min, wire tension is 6N and peak current is 4A. Amitava Mandal, et al.[19], worked on improving the performance parameters like cutting rate, spark gap, wire wear ratio and surface roughness using electra maxicut 734 CNC WEDM with zinc coated brass wire and Nimonic C-263 super alloy as work piece. The parameters taken into consideration were pulse on time, pulse off time, servo voltage and dielectric flow rate. The methodology applied was response surface methodology and found that maximum cutting rate of 2.224mm/min and minimum spark gap of 40µm obtained when pulse on time is 1.35µs, pulse off time is 120µs, and servo voltage is 35v and dielectric flow rate is 4 litres per minute. This paper also says that minimum surface roughness of 1.38µm was obtained when pulse on time is 0.95µs, pulse off time is 200µs, and servo voltage is 75v and flow rate is 8 litrs/min. The maximum wire wear ratio was obtained when pulse on time is 1.35µs, pulse off time is120µs, servo voltage is 75v and flow rate is 8 lt/min. Bijendar singh, et al.[20], worked on improving the performance parameters like material removal rate and surface roughness using electronica sprintcut CNC WEDM with brass wire and stainless steel 410 as work piece. The process parameters taken into considerations were pulse on time, pulse off time, wire tension and wire feed. In this paper the methodology applied was Taguchi and regression analysis and found that maximum removal rate of 4.2mm^3 /min and wire tension is 11g. And also, minimum surface roughness of 3.79µm was obtained when pulse on time is 121µs, pulse off time is 55µs, wire feed is 5mm/min and wire tension is 9g. Dhresh H Gajjar, et al.[21], worked on improving the performance parameters like material removal rate, surface roughness and kerf width using electronica sprintcut CNC WEDM with molybdenum wire and EN31 tool steel as work piece. The process parameters taken into consideration were pulse on time, pulse off time, and servo voltage. In this paper, the methodology and found that best MRR, kerf width(KF) and surface roughness (Ra) are obtained when pulse on time is 130μs, pulse off time is 60μs and servo voltage is 30v. Dodun Oano, et al.[22], worked on improving the performance parameters like cutting speed, surface roughness and wire wear ratio using Japax L250A CNC WEDM by taking alloyed steel 205Cr115 as work piece. The process parameters taken into consideration were wire speed, pulse off time, pulse on time and wire tension. In this paper, the methodology applied was grey relational analysis (GRA) and Taguchi approach and found that best cutting speed (CS), wire wear ratio (WWR) and surface roughness were obtained when pulse on time is 0.5μs, pulse off time is 0.066μs and current is 0.5A. Ganesh Dongre, et al.[23], worked on improving the performance parameters like kerf loss, slicing speed and surface roughness using electronica WEDM with molybdenum wire and silicon waber as work piece. The process parameters taken into consideration were peak current, dutycycle, work piece height and wire diameter. In this paper, the methodology applied was Response surface methodology approach and found that optimization of kerf loss to 50μm and slicing speed to 2.5mm/min is obtained when peak current is 1A, wire diameter is 40μm and duty cycle is 50%. Milton Peter J, et al.[24], worked on Improving the performance parameters like material removal rate and surface roughness using ezecut plus EZ01 WEDM with brass wire and Inconel 718 as were pulse on time, pulse off time, wire feed and gap voltage. In this paper, the methodology used was Taguchi method and found that pulse on time is the most significant parameter for material removal rate and while the gap voltage has the most influences on surface roughness. Ramamurthy A, et al.[25], worked on improving performance parameters like material removal rate and parameters like material removal rate and surface roughness using electronica CNC WEDM with Titanium alloy as work piece. The process parameters were pulse on time, pulse off time, servo voltage, wire material and peak current. In this paper, the methodology used was Taguchi and grey relational analysis and found that maximum MRR is 0.0025mm^3/min and the minimum surface roughness is 2.095μm was obtained when pulse on time is 30μs, pulse off time is 90μs, servo voltage is 80v and peak current is 4A. Sachin Dev Barman, et al.[26], worked on increasing the performance parameters like cutting rate and surface roughness using electronica elplus 40A sprintcut WEDM with brass wie and tungsten carbide as work piece. The process parameters considered were pulse on time, pulse off time, peak current and wire feed rate. In this paper the methodology used was Grey relational analysis and Taguchi approach and made several experiment and found that GRA tool is effective tool for optimizing and optimal machining conditions obtained are pulse on time is 18μs, pulse off time is 40μs, peak current is 200A and wire feed is 7mm/min. Sivaraman B, et al.[27], worked on improving the performance parameters like surface roughness and material removal rate using maxicut WEDM with brass wire and titanium as work piece. The process parameters taken into consideration are pulse on time, pulse off time, gap voltage, wire tension, wire feed rate and table feed. In this paper, the methodology applied was Taguchi method and conducted several experiments and found that from the optimization it is found that maximum MRR of 0.823g/min and minimum surface roughness of 1.687μm obtained when pulse on time is 5μs, pulse off time is 7μs, gap voltage is 5volts, wire tension is 900g, wire feed is 7mm/min and table feed is 6mm/min. Jakalai A M, et al.[28], worked on improving the performance parameters of surface roughness and material removal rate using electronica sprintcut734 CNC WEDM with AISI 304 steel as work piece. The process parameters considered were pulse on time and peak current. In this paper, several experiments were conducted using Taguchi method and found that the pulse on time and peak current increases with increase in MRR and surface roughness increases, as pulse off time increases. Vivek Agarwal, et al.[29], worked on improving the performances paremeters like cutting rate and surface roughness using electra sprintcut 734 with zinc coated brass wire and Inconel 718 as work piece. The process parameters were wire tension, pulse on time, pulse off time, wire feed and servo voltage. In this paper, the methodology used was response surface methodology and found that highest cutting rate 2.55mm/min and lower surface 14µs, wire feed is 5.97g, servo voltage is 16v, wire tension is 691.78g, pulse on time is 0.62µs and peak current is 210A. Vijaybabu T, et al.[30], worked on improving the performance parameters like material removal rate and surface roughness using elecronica under cut CNC WEDM with brass wire and titanium as work piece. The process parameters are pulse on time, pulse off time, peak current, wire tension, servo voltage and servo feed. In this paper, several experiments were conducted using Taguchi approach and found that best surface roughness was observed at pulse on time is 128µs, pulse off time is 46µs, servo voltage is 30v, wire tension is 6mm/min and peak current is 220A. The best MRR was observed when pulse on time is 112µs, pulse off time is 60µs, servo voltage is 70v, wire tension is 6mm/min and peak current is 150A.

Methodology:

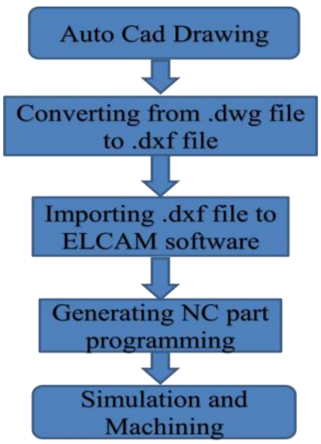

Fig 1. Flow chart for machining procedure

Copper and Aluminum metals of 30mm and 32mm diameter rods are used to fabricate the micro electrode arrays. Initially a 10x10 array of height 0.6mm height and width of each square electrode 0.03mm and the gap between two square electrodes 0.07mm is assumed. But, the width of the square electrode is smaller than the diameter of the wire. Hence, technically it is impossible to get a 10x10 matrix with that dimensions. Then, the scale is increased to 15 times and 22 times keeping the initial matrix as base matrix.

After increasing the base matrix 15 times, the dimensions changed are as follows.

- Height of square electrode :9mm

- Width of each square electrode :0.45mm
- Gap between two square electrodes :1.05mm

After increasing the base matrix 22times, the dimensions changed are as follows:

- Height of square electrode :13.2mm
- Width of each square electrode :0.66mm
- Gap between two square electrodes: 1.54mm.

A 3x3 matrix of 30mm diameter rod, dimensions are as follows.

- Height of square electrode :6mm
- Width of each square electrode :4mm
- Gap between the two square electrode: 4mm

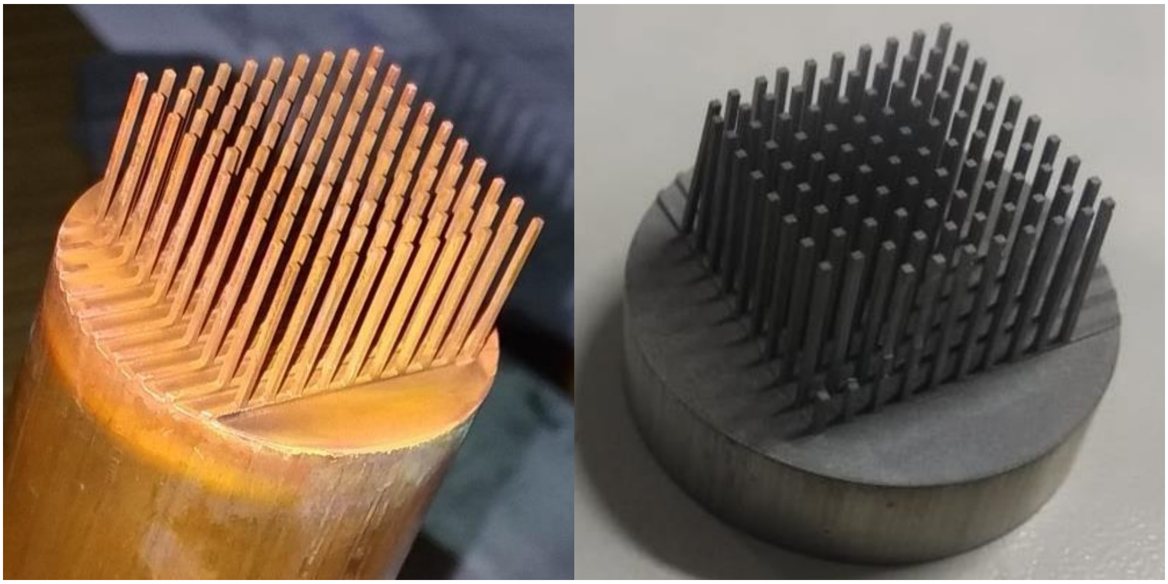

Fig 2. 10x10 Square matrix electrodes after machining

Conclusion

In the current research work Wire EDM is used for making microelectrode arrays of different dimensions and array sizes. Process of micro-WEDM technology for microelectrode array fabrication is assessed. Initially a 10x10 base matrix of height 0.6mm, width of each square electrode 0.003mm and the gap between the two square electrodes 0.007mm is assumed and the scale is increased to 15 times and 22 times. Hence, the 10x10 array of 15 times and 22 times scale were fabricated with aluminium and copper work pieces. Besides these micro electrode arrays, a 3x3 micro electrode array of height 6mm, width of each square electrode 4mm and the gap between the two square electrodes 4mm is fabricated. And also a 10x10 array matrix of 22 times increase in scale is fabricated with curved base. These micro electrode arrays which were fabricated are having high dimensional accuracy, very smooth surface finish and cut precisely. The corners and the edges of array electrodes were cut very accurately and the strength of the electrodes is also very high. But, for the fabrication of these micro electrode arrays takes lot of time and there may be some of the troubles like wire breakage, dielectric purification, etc. However, the time taken can be reduced by changing the process parameters like pulse on time, pulse off time, servo voltage, peak current, wire tension, wire feed, etc. And also the wire breakage can be reduced by optimizing the process parameters while machining. By this, the performance parameters can also be achieved according to the requirement. These micro electrode arrays can be used for creating impressions using sinker EDM. These micro electrodes arrays will be used as tools in sinker EDM and can create impressions on another work piece. By this a lot of time will be saved and can also be achieved with high accuracy. This new technology of large scale micro electrode array fabricated by micro WEDM is proved to be feasible and high efficient.

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