Optimization of Electric Discharge Machining parameters with Different types of Porous Structured Electrodes using distributed Multi hole inner flushing.

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By

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled **"Optimization of Electric Discharge Machining parameters with Different types of Porous Structured Electrodes using distributed Multi hole inner flushing."** in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of (Mr. Jasvir Singh (14631) , assistant professor) Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

(28 April 2017)

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

In the past years many researchers have done various advancements in material removal rate, wear of electrode is improved and various researches had done on physical and electrical parameters of EDM machine. This new research contribute the similar objectives to enhance the material removal rate and to increase the life of electrode by reducing the wear rate of electrode. So this paper review the past research work done to improve the life of electrode and to reduce the lift up time of electrode to flush debris and various work on porous electrodes to reduce lift up time. In this research, porous electrodes by diffusion bonding (sintering) of copper are made in practice to achieve best porous structure. Different size of copper granules and chips are used. Also describing the running research technique trend in EDM, upcoming EDM research direction.

CHAPTER 1 (Introduction)

Electrical discharge machining is the advances machining process in which there is no direct contact between the workpiece and the electrode and the material erodes with the spark and it happens in presence of the dielectric fluid. The workpiece material required to be electro conductive. EDM machine has a wide variety of work like production of die cavities with large enough components, deep holes and precise intricate holes. The EDM history started as far as 1770, when the English chemist Joseph Priestly found erosive effects of electric discharge and sparks. It was invented by two different scientists belongs from Russia, DR. B.R. Lazarenko & DR. N.I. Lazarenko in 1943. The spark generator was first used in 1943, known as Lazarenko circuit. And it was used for many years in power supply for EDM. Also been used in many current applications. Lazarenko circuit used resistance capacitance type of electric supply source. And was broadly used in 1950's also played an important role later in successive improved development in EDM. Other development in 1960's was pulse and solid state generator reduced past problems with weak electrodes as well as inventions of orbiting system. And while 1970,s a number of electrodes were introduced to create cavity. And further in 1980s the computer numerical controlled (CNC) was introduced in USA.

1.1 COMPONENTS OF EDM:

1. Work piece: all the material which conducts electricity can be the workpiece material for EDM.
2. Dielectric fluid: EDM setup consist of dielectric fluid in which the electrode and the workpiece material is submerged.
3. Servo system: It feed the electrode by sending the voltage in terms of pulse by command of servo system.
4. Electrode: it is the tool of EDM which determine the shape of work piece cavity to be made.
5. Power supply: the power supply is the main part of EDM system, which convert the AC in to DC in means of pulse. To gain the discharge at machining zone.

6. DC pulse generator: it supplies the DC current in the pulse form, with the suitable currant and voltage value for specific amount of the time.

1.2 PRINCIPLE OF EDM:

The principle of EDM is to use the electric spark to erode the workpiece by setting some amount of voltage and current value as how much amount of spark we need to erode material. These sparks are produced in dielectric fluid in between the workpiece and electrode. And this spark can be considered as the actual cutting tool. As much the intensity of current as much it penetrate the workpiece material. And yet there is no mechanical contact between workpiece and electrode. During the spark formation the workpiece material melt or vaporize due to the much amount of heat. The volume of material removed by the single spark is small. It is basically in the range of 106-104 mm3, but this basic process repeats at least 10,000 times in a second. The first voltage which is generally given is of 200 v. and the breakdown of the dielectric is achieved when the electrode moves towards the material of workpiece. And it increases the electric field in the zone of gape and in increases until reaches the value until the breakdown takes place. The location of breakdown is basically the closet point of the electrode and workpiece material. And it also depends how much dielectric particles present as the location. When the breakdown occur the voltage value gets down and the current increase abruptly. And now the presence of current is possible in the dielectric. Because the dielectric has been ionized at this state and a plasma is generated over in the gap between electrode and workpiece. A discharge current then formed and continuous bombardment takes place which is of ions and electrons. And hence the great heating of metal takes place, and the molten metal pool form at the location, from which some amount of metal vaporize at the starting. And the molten metal pool increase in size with time. The gap between the work piece and electrode is also a very important parameter. Typically it is to be around 10-100 micro-meter (increasing gap with increasing discharge current should be there else the penetration will be very high). At the end of discharge the current and voltage should be shut down. The plasma implodes in and under the pressure of dielectrics. Hence the metal pool is sucked up into the dielectric. Which leaves the small crater on the surface of workpiece of material.

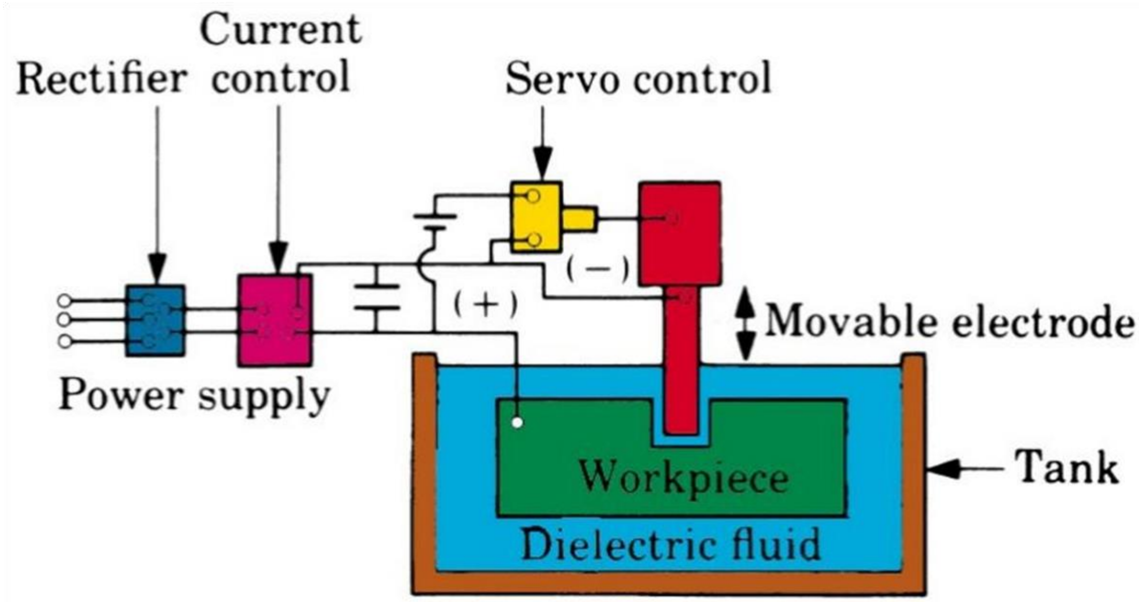


Figure 1 principle of edm

1.3 MAJOR PARAMETERS OF EDM:

These parameters generally categories in two major parts: (a) Process parameters and (b) performance parameters.

1. Process parameters: these are used to handle the performance machining. And are generally the changeable and controllable inputs to the machine. And measures the condition in which the machining process is carried out. And these will affect the result of machining and are used by gauging many performance measures.

   A. Electrical parameters:

      1. Polarity
      2. Discharge voltage
      3. Gap voltage
      4. Peak current
      5. Average current
      6. Pulse ON time
      7. Pulse OFF time

8. Pulse frequency
9. Pulse wave form
10. Electrode gap
11. Duty factor

B. Non electrical parameters:

1. Electrode lift time
2. Working time
3. Nozzle flushing
4. Gain
5. Type of dielectric

C. Powder based parameters:

1. Powder type
2. Powder concentration
3. Powder conductivity
4. Powder size
5. Powder density

D. Electrode based parameters:

1. Electrode shape
2. Electrode size
3. Electrode material

2. PERFORMANCE PERAMETRERS:

Helps in identify and measure the various result of various process.

Measure	Importance
Material removal rate (MRR)	It is the performance measure for the erosion rate, or we can say it tell the speed of machining of the workpiece. It expressed in terms of volumetric amount of the workpiece.
Tool wear rate (TWR)	It is the performance measure which tell the erosion rate of the tool, or we can say at what amount of speed the tool is degrading. It is expressed in terms of volumetric amount of the tool.
Tool ratio (TR)	It is the ratio of TWR/MRR. It is used to measure the optimum combination of material to compensate the TWR and MRR.
Surface quality (SQ)	It is a huge performance measure, helps in finding the HAZ, surface finish and how is the quality of machined surface. And also include the detail of density of recast layer.
Surface roughness (SR)	It is the surface parameter, measures the amplitude variation of the surface. Which translate to roughness. It include detail of Ra(mean roughness), Rmax and Rq (mean square surface roughness)
Heat affected zone (HZ)	It is the volume of workpiece which didn’t melt during the discharge, but affected and transformed the phase as similar to the heat treatment.
Recast layer thickness	It is the layer which solidifies again after melting, due to not proper flushing or because of the cold slow flushing.

Table 1 Performance parameters

1.4 TYPES OF EDM:

Generally there are two types of EDM:

1.4.1 DIE SINKING EDM:

It is the cavity type or volume EDM. This in used to make cavity or making the dies. In this workpiece and electrode are submerged in dielectric fluid. The work and electrode are connected to suitable power supplies. The power supplies create the voltage potential. As the electrode move towards the work, the dielectric breaks. And form a plasma channel. And the spark jumps. These spark strike one at a time usually. Because it is very difficult that the inner electrode have same electrical properties at all the point if plane. And thus the spark changes the location. These spark happens in huge amount in all the location and metal melts. And when the work erodes the electrode automatically goes down by machine itself so that the process continues.

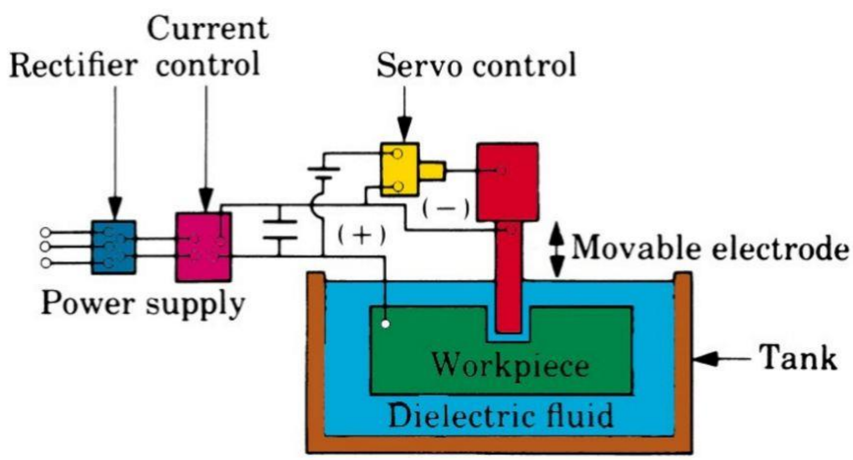


Figure 2 Die sinking EDM

1.4.2 WIRE EDM:

Wire EDM also known as the spark EDM. It is the electro thermal production process. In this process single metal strand wire is used to machine the work in conjunction with de-ionized water (used to conduct electricity) allows the wire to cut metal by the use of electrical sparks and heat. And also the workpiece is submerged in tank of dielectric. It can cut plates as thick as 300mm and to make the punching tools, the die of hard metal can also be form which are hard to machine. The benefit is the low residual stress forms. Very less mechanical properties of the work changes.

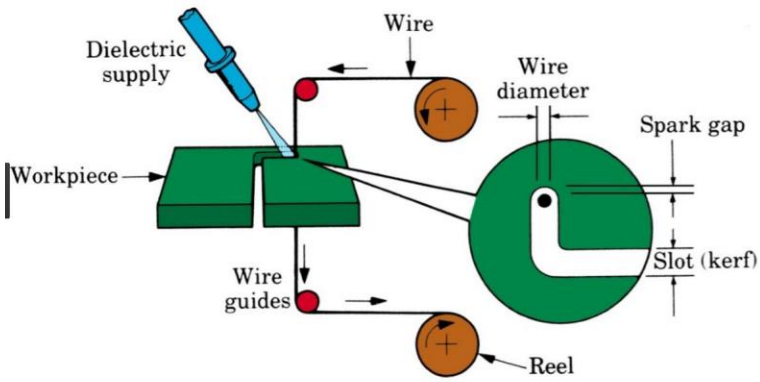


Figure 3 wire EDM

1.4.3 ADVANTAGES OF EDM:

1. +/- 0.005 tolerance limit can be achieved.
2. Material hardness does not affect process.
3. Complex shapes cutting and thin walled geometry can produce without distortion.
4. EDM process has no-contact and no-force that make it well suited for delicate or fragile parts that cannot take the stress of traditional machining.
5. The EDM process produces no burrs.

1.4.4 DISADVANTAGES OF EDM:

1. Can only machine materials which are conductive.
2. Much expensive process than conventional milling or turning methods.
3. Slow production rate.

1.4.5 APPLICATION AREAS OF EDM:

1. To make hardened steel dies, wire drawing and extrusion dies, header dies, stamping tools, header die, forging die and intricate mold cavities.
2. Best for making fragile parts which are very sensitive to mechanical forces.
3. Micro pins, cavities and micro nozzle can be easily produced.

1.4.6 EDM ELECTRODE MATERIALS:

EDM electrode materials need to have properties that easily allow charge and yet resist the erosion that the EDM process encourages and stimulates in the metals it machines. Alloys have properties which provide different advantages based on the needs of the application.

Brass is an alloy of copper and zinc. Brass materials are used to form EDM wire and small tubular electrodes. Brass does not resist wear as well as copper or tungsten, but is much easier to machine and can be diecast or extruded for specialized applications. EDM wire does not need to provide wear or arc erosion resistance since new wire is fed continuously during the EDM wiring cutting process.

Copper and copper alloys have better EDM wear resistance than brass, but are more difficult to machine than either brass or graphite. It is also more expensive than graphite. Copper is, however, a common base material because it is highly conductive and strong. It is useful in the EDM machining of tungsten carbide, or in applications requiring a fine finish.

Copper tungsten materials are composites of tungsten and copper. They are produced using powder metallurgy processes. Copper tungsten is very expensive compared to other electrode materials, but is useful for making deep slots under poor flushing conditions and in the EDM machining of tungsten carbide. Copper tungsten materials are also used in resistance welding electrodes and some circuit breaker applications.

Graphite provides a cleaning action at low speeds. Carbon graphite was one of the first brush material grades developed and is found in many older motors and generators. It has an amorphous structure.

Molybdenum is used for making EDM wire. It is the wire of choice for small slot work and for applications requiring exceptionally small corner radii. Molybdenum exhibits high tensile strength and good conductivity, making it ideal where small diameter wire is needed for demanding applications.

Silver tungsten material is tungsten carbide particles dispersed in a matrix of silver. Silver offers high electrical conductivity and tungsten provides excellent erosion resistance and good anti welding characteristics in high power applications. This composite is thus the perfect choice for EDM electrode applications where maximizing conductivity is crucial.

Tellurium copper is useful in EDM machining applications requiring a fine finish. Tellurium copper has a machinability that is similar to brass and better than pure copper.

1.4.7 EDM MATERIAL PROPERTIES:

1	Materials	Electrical conductivity (Siemens/m)	Electrical Resirtivity (ohm.m)	Melting point
2	copper	58.5	1.7	1083
3	zink	16.6	6	419
4	Brass	15.9	6.3	900
5	Aluminium	36.9	2.7	660
6	Tungsten	8.9	11.2	3422
7	graphite	increase with rise in temp	decrease with rise in temp	no melting point below 100 Atmospheres

Table 2 EDM material properties

CHAPTER 2 (LITRATURE REVIEW)

T. Shibayama and M. Kunieda et al. (2006) [1] Researched on EDM electrode made with the help of electrolyte jet machining, they created multi-channel on copper electrode having width of 10mm and thickness 2mm. they made it in two half and then bonded these two half with the help of diffusion bonding at a temperature of 1073 K, bonding force 9 MPa and loading time was 120 minutes. They compared two experiments one with dripping with medium flow and jump flushing. Material removal rate for drip flushing was two times higher than the flow flushing. Also there were no problem faced in creating deep groves in both the methods. And the same geometry of tool was replicated because the holes were in size of 0.12mm.

Y. H. Guu et al. (2007) [2] researched on workpiece rotation effect on EDM. They found it effective to use, results indicated that debris Particles in the gap inevitably increased the discharge instability in conventional EDM. Also the centrifugal forces helps in gap flushing. Surface roughness decrease with increasing speed. MRR was found twice if the previous method.

D. J. Thewsey eta al. (2008) [3] researched on thermal conductivity of porous copper sintered by lost carbonate process. And they got that electrical conductivity increases with the relative density. Also thermal conductivity increases with the relative density was observed. Both the values were a bit different cause the impurities and oxides contribute to the thermal conductivity but not to the electrical conductivity.

Jianfeng Zhao et al. (2013) [4] researched on Selective laser sintered electrode and they found that it can be used as EDM electrode if they use it for rough or medium finishing operations. The surface roughness of the cavity the electrode made was acceptable.

Santanu Dey et al (2013) [5] researched on graphite and copper electrode and they found that for lower values of parameters generally for finishing the graphite electrode is superior, but for the maximum MRR the copper electrode is best on higher value parameters where finish requirements are not significantly desired.

A. Antenucci et al. (2014) [6] researched and found that for the copper foam the thermal conductivity is enhanced by 60-70% and they examined that the resistance is directly proportional to the density.

P. Balasubramaniana (2014) [7] Researched on cast and sintered electrode performance on EN-8, he found that the MRR is more for sintered copper electrode, and tool wear wear rate is also high but the wear ratio was less. And he found that the surface roughness was less for cast electrode. But the results were opposite for the workpiece Die steel. The reason was the electrical parameters was different for machining different workpieces

Qingyu liu et al. (2015) [8] researched effect of parameters on the tool electrode wear, he found due to skin effect and area effect the MRR, WEAR RATE, TAPER rate are different with increase in dia of the tool. Large dia result in higher MRR along with higher tool wear rate. The electrode wear rate is more than the work wear rate. Which leads to increase in tool wear ratio. A tool electrode with higher dia also result in increase in taper rate.

Rimao Zou et al. (2016) [9] researched on porous structured steel workpiece and machined it with EDM, and they found that MRR increase with the increase with the pour size. And the minimum MRR is result when the pour size is minimum. Also we can say when the pour size is less than the spark gape it results in minimum MRR.

Sangeeth suresh et al. (2016) [10] Researched on the work material (Ti6Al4V), with three different electrodes, copper, brass and graphite. And they found that the electrical resistivity and melting point of electrode influence the wear of electrode and MRR of ti6al4v work material. The graphite electrode was more superior to machine this work. It achieved near indented depth, as graphite less resist the electricity and the wear was less as compare to copper and brass.

Ankur shriwastava et al. (2016) [11] Researched on three electrodes of different material, copper, brass and graphite and they found copper provide superior performance on productivity, also they found that the carbon layer on the work material was very high as compare to other electrode, and they choose the work material aluminum alloy 6061. And they find from the surface finish point of view the graphite electrode was superior. And also by research it is clearly understood that the white layer thickness depends on the electrode material, and is it minimum for brass.

JIANG Yia et al. (2016) [12] researched on die sinking EDM, they replaced the typical tool with the porous electrode of copper, made with the copper balls which are sintered on temperatures for different sample of electrodes. And they found that the MRR improved. Or we can say it as the rough machining ability improved because there the surface finish was poor cause of the non-uniform porous structure of the electrode.

Anand Prakash dwevedi and sounak Chaudhary (2016) [13] did a research on EDM MRR improvement by rotating the electrode while machining, and they found that the MRR improved by 41% and also the recast layer thickness reduced. And resulted a uniform surface with miner cracks. And surface roughness improved by 12%.

Rodrigo P. Zeilmann et al. (2016) [14] The position of flushing path has an important impact on the subsurface hardness because of the facility or difficulty of heating and melt or debris removal. This affects the diffusion of carbon and hydrogen into the workpiece. An improper flushing causes the increase in subsurface hardness.

APIWAT MUTTAMARA et al. (2016) [15] Found that carbon has a very important role in forming recast layer in EDM machining, the carbon layer produced in kerosene is rougher and thicker, then the layer formed in deionized water. In addition the layer formed on gray iron is rougher then the mild steel. And they found that the micro cracks on the layer found were longer in case of water. But in kerosene they were wider. Also the discharge duration effects the crack formation. Longer duration causes longer micro cracks.

Jonas Holmberg et al. (2016) [16] The results show that grit blasting is a possible method to be used in order to remove RCL after EDM processing. The grit-blasting parameters blasting time and nozzle distance have great influence on the resulting surface integrity generating a RCL-free surface with high compressive residual stresses after exposure times greater than 4 s.

Hui-Ju Chan et al. (2017) [17] Researched and found that if we do sintering on Nano particles of copper, the reduction of porosity in the single film of particles was 37.3%, and the roughness of surface film also decrease by 65.7%. Also the elimination of oxygen content in thin was 91.7%.

Shahabeddin K. Mohammadian et al. (2017) [18] Researched on aluminum foam for heat sinks and they found that porous foam insertion improves temperature reduction. And also this practice enhance the temperature uniformity.

Siliang Yin et al. (2017) [19] made a flexible electrical electrode, they made is with the help of facile thermal evaporation, bilayer is made with CU and Al was made with this technique. Whose resistivity has been greatly decreased to 3.05 μΩ·cm. The introduction of Al buffer layer gave a complete growth crystalline of Cu with decreased residual thermal stress. And achieved a very great flexibility.

Koyano, et al. (2017) [20] Made a porous electrode for electro chemical machining, by selective laser sintering. The size of pours can easily be achieved in different size just by varying the speed of selective laser sintering process. If the laser move fast, pours will be of larger size and vice versa. They also found that small pour size and uniformity in size can help in getting good machining. Also decrease in the porous area can be helpful if sufficient flow of electrolyte can be achieved.

Xu, H. et al. (2017) [21] researched on multi hole EDM electrodes with various size of hole diameters. The electrodes they used are made of graphite. They made three electrodes with different arrangement of holes. And the arrangement was E1(2,2,2,2)mm, E2(2,3,2,2)mm, E2(2,3,2,1.5)mm holes radially. The first hole was in the center rest three are about radially. And number of holes of in radially were (1, 6, 12, and 18). They found that E3 electrode has the best MRR and low TWR. The faster the flushing pressure the faster the plasma break and it also helps in increasing the MRR. Also the faster the flushing velocity it is fast to carry away the heat from electrode and it helps in increase in tool life.

Suarez, et al. (2016) [22] In this research Borax powder was used as a flux in the sintering process of iron anchor steel 1000R, and they found that borax works as a lubricant too and help in keeping the sintering part separated from the die. And also they found that it can help in maintaining the porosity inside the part. The more the flux used the higher the porosity they get. The percentage of borax they used in mixture was o.5% to 6% and the porosity range they got was from 7.88 to 13.10%. Research also shows that micro hardness increase with increasing borax percentage and decreasing sintering temperatures.

Ohdar, et al. (2017) [23] Researched on EDM of steel 2023 with the help of copper on various parameters and found that for MRR, most important factor is pulse ON and OFF time. On peak current value 12A, pulse ON time 15 micro seconds and pulse off time 3 micro seconds with flushing pressure 0.3kg/cm3 it is observed that MRR becomes high. For TWR the important found is peak current followed by pulse ON time. At the value of peak current 14A, pulse ON time 5 micro seconds and pulse OFF time 7micro seconds TWR reduced.

Singh, et al (2017) [24] used and air assisted multi-hole tool to machine high chromium high carbon die steel, also provided rotation to the tool. The high pressure of argon gas with the rotation of tool helped in keeping the molten drop away from the machining section very fast. Also the tool wear decrease due to the passage of air. MRR significantly increased.

Olatz Fla˜no and Yonghua Zhao, et al. (2017) [25] they used copper foil electrode to cut SiC, the foil was having hole cutting inside and they called it chip pocket cause it helps in removing debris white machining. Improved MRR was observed when the jump motion provided to tool. Holes in foil also helped in cooling down the foil temperature.

CHAPTER 3 (OBJECTIVE OF RESEARCH)

The objective of research is to increase the production rate with the EDM process. The EDM process consume very much time to machine the work. So with this research we mean to reduce the process time by reducing or eliminating the tool lift up time. We will use porous tools to machine the works and to remove the molten metal we wouldn't lift up the tool but we will directly apply the flush pressure of dielectric to the works molten metal pool to remove the molten metal. The dielectric will go through the inside of porous electrode. And hence we don't have any need to lift up to tool to remove the melt. Also the rotation will be provide to electrode to gain the surface finish of work. Because the porous electrode have the only main disadvantage that is wouldn't be able to give finished surface. So by this project we will work in progress to increase the MRR, reduce the wear of tool, as the cold dielectric fluid will pass through the tool the tool wouldn't melt easily, and to increase the surface finish. The white layer and redeposit layer will also we reduced as the centrifugal force pull the layer to sides and removed by the flushing pressure.

a. Reduce machining time.
b. Improve tool life
c. Increase surface finish
d. Increase MRR

Workpiece material: **AISI D3 tool steel** will be taken as workpiece material. The material is chosen because of wide variety of applications in industries. And due to excellent abrasion/ wear resistant property it is hard to machine by conventional methods. It has very high dimensional and high compressive strength having hardness range 58-64 HRC, in hardened condition D3 machining is limited to finish grinding.

Applications of workpiece material:

1. Stamping, blanking and cold forming die & punches.
2. Forming rollers.
3. Punches
4. Bushes

Materials and equipment required for experiments:

1. Pure copper balls of two sizes 1mm to 3mm dia.
2. Pure copper chips (chopped)
3. Graphite molds (25*30*50mm)
4. Sintering flux
5. Graphite leads (0.5mm)
6. Muffle furnace (for sintering)
7. Compaction die
8. EDM machine

CHAPTER 4 (METHODOLOGY FOR ELECTRODE PREPRATION AND SETUP)

1. Making of graphite molds: Graphite rods are used to do the sintering of copper balls and chips so that bond can be created with the help of fusion. As the graphite mold have no melting temperature on normal pressure. Graphite molds only weaken when they come in contact with air so reducing environment should be created. And also the graphite have frictionless properties so after the sintering of electrode it will be easy to remove the electrode from mold.

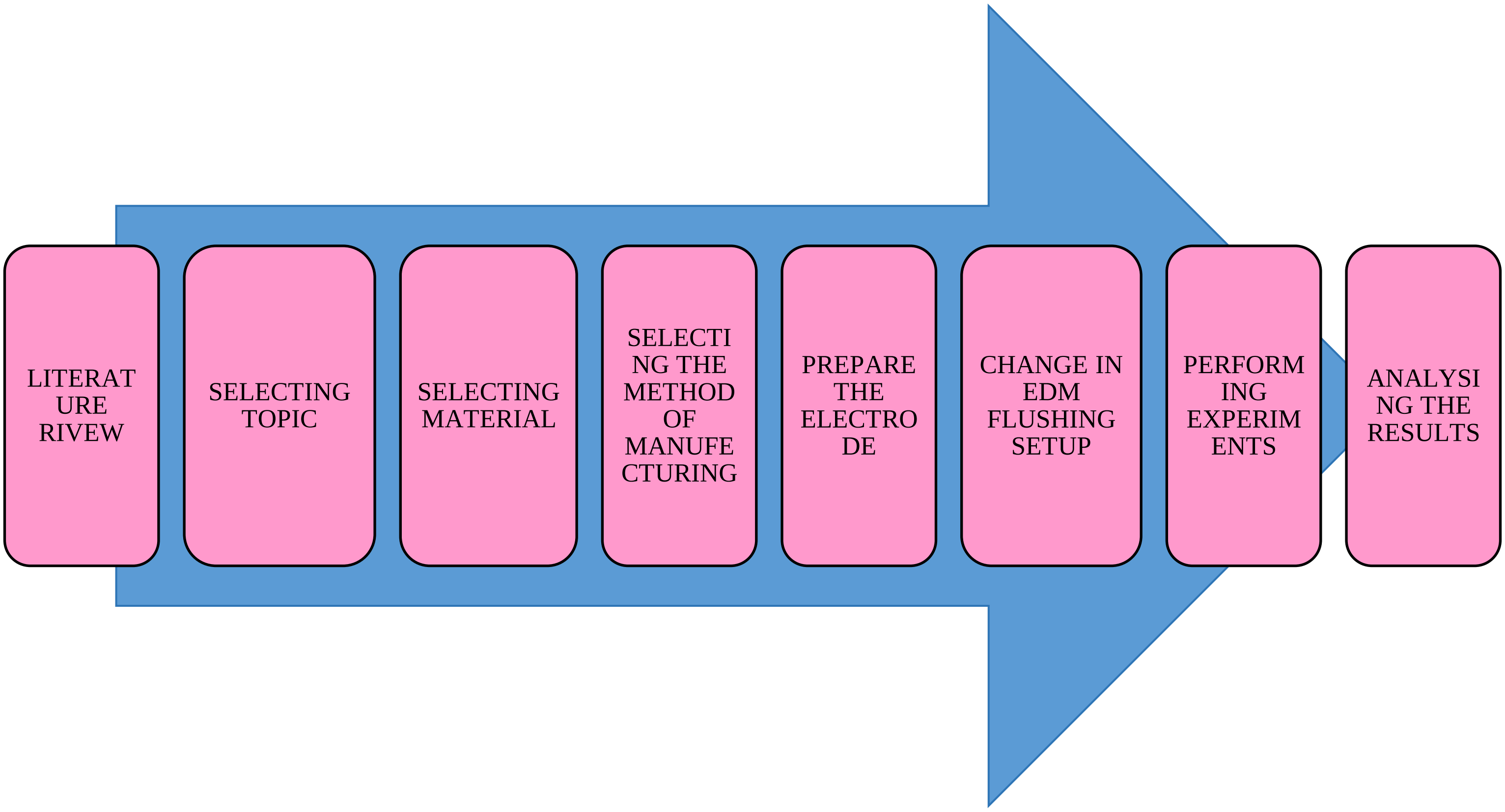
   Graphite rod of 30mm outer dia is to be taken and internal turning of 25 mm dia to be done for making cylindrical cavity in which the actual sintering of copper balls and chips to be done.

   Four molds of the same geometry to be made because the life of a graphite mold is of near to the 5 time of sintering use because they are made with graphite clay and bonding strength decreases with time.
2. Compaction die are made with the same working phenomena as mechanical screw press. For proper bonding of particles we need to apply some pressure at the time of heating only so that each copper element can bond with each other and this will also help in reducing the oxidation as the gas would not come in contact with the compressed or compacted particle. Pressure will be applied with the help of fastening the nuts.
3. Borax will be used as a flux to make protective layer so that it reduce the oxidation of metal. Borax powder will be covered on the copper particles which are to be bonded by diffusion. Also it will help in maintaining porosity as the researches shows that borax can help in maintaining porosity.
4. Sintering is the process by which these porous electrodes are to be made because the low pressure sintering allow us to create huge porous gape which is not possible by high pressure or highly compressed sintering, in this type of sintering the temperature required are high as compare to the high compression or high pressure based sintering.

   Three types of heating schedules can be used in less-pressure sintering:

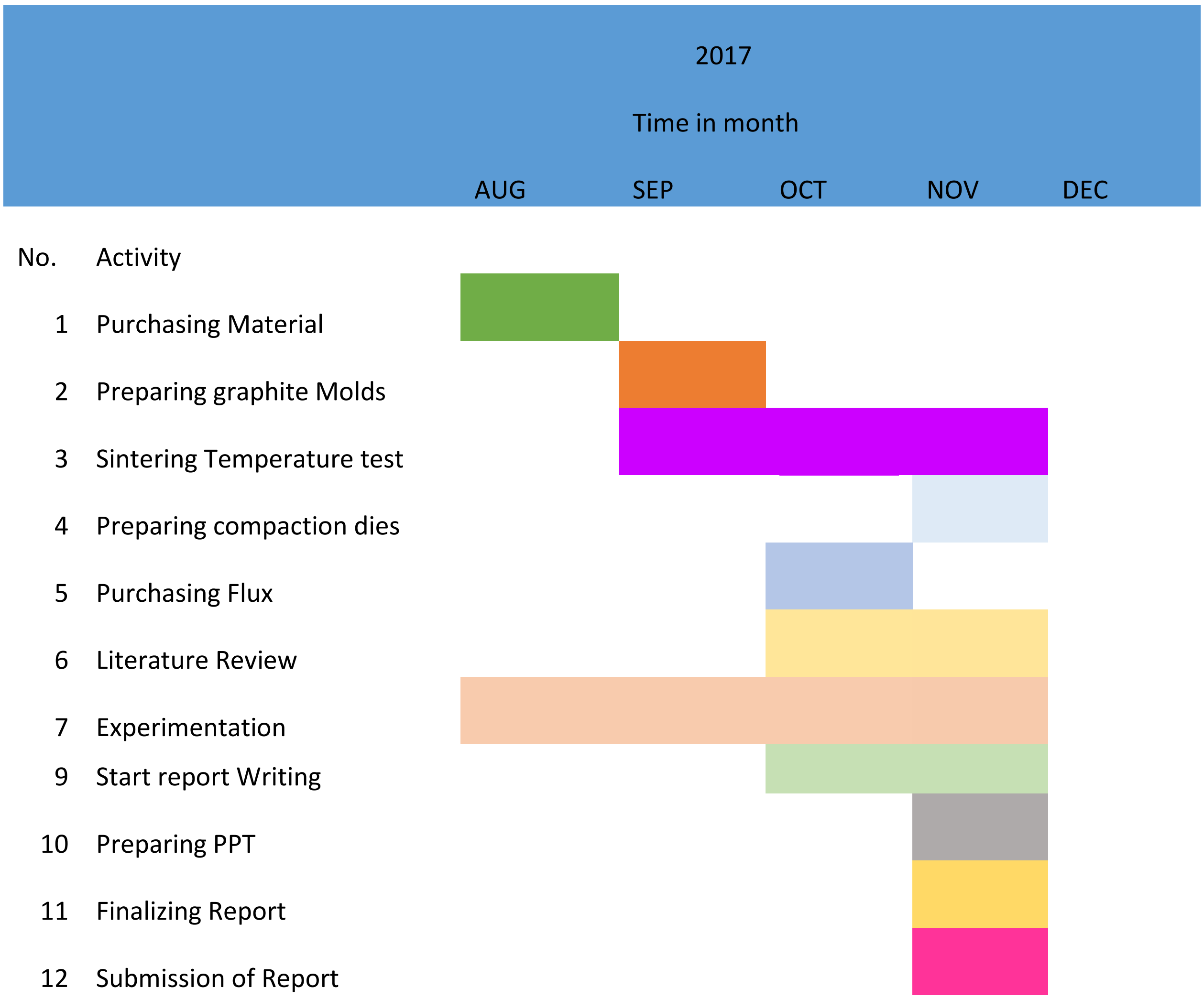
   a) Constant Rate of Heating (CRH): also known as the temperature controlled sintering. In this the rate up of heating is constant. Reaches to final temperature with constant rate given.
   b) Rate Controlled Sintering: in this controlling of heat rate and temperature both can take place. Degree centigrade per minute values can be changed throughout.
   c) Two step sintering: in this type of sintering two different sintering temperatures are used. First temperature should generate relative density greater than 75% of theoretical density. Then the part is to be cooled down and again sintering is to be done on second temperature.

5. Finally after making of electrodes we need to make a different type of electrode holder which can hold porous electrodes with well grip and need to make the design like that it can install the flushing pipe into it.



1. Literature review
2. Selecting Topic
3. Selecting material
4. Selecting the method of manufacturing
5. Preparing of electrode
6. Change in EDM flushing setup
7. Performing experiments
8. Analyzing results

CHAPTER 5 (PROPOSED WORKPLAN WITH TIMELINES)



CHAPTER 6 (EXPERIMENTAL WORK)

Table 3 Process parameters and their levels

Parameters	Level-1	Level-2	Level-3
Pulse ON time (µs)	100	200	300
Pulse OFF time (µs)	40	50	75
Flushing pressure (Psi)	3	4	5
Type of porous Electrodes	Ball dia(1.5mm)	Ball dia(3mm)	Chips

Table 4 Design of experiments

No. of experiment run	Pulse ON time (µs)	Pulse OFF time (µs)	Flushing pressure (Psi)	Electrode type
1	100	40	3	1.5(ball)
2	100	50	4	3(ball)
3	100	75	5	chips
4	200	40	3	1.5(ball)
5	200	50	4	3(ball)
6	200	75	5	chips
7	300	40	3	1.5(ball)
8	300	50	4	3(ball)
9	300	75	5	chips

Three type of porous copper electrodes are to be made, two are of different size of copper balls and one of copper chips. Above 9 no. of experiments are to be run on each type of electrode and we need to analyze on what run of parameter values we are getting best results for each electrode. Total 27 no. of experiments we need to perform in this research after completing preparation of electrodes. L9 table for each of three type of electrodes will be same made with the help of Taguchi parameter design. Also at the final we need to compare which type of electrode is superior.

Note: Peak discharge current and Gap voltage will be kept constant for each experiment and the values will be 10A and 100V respectively.

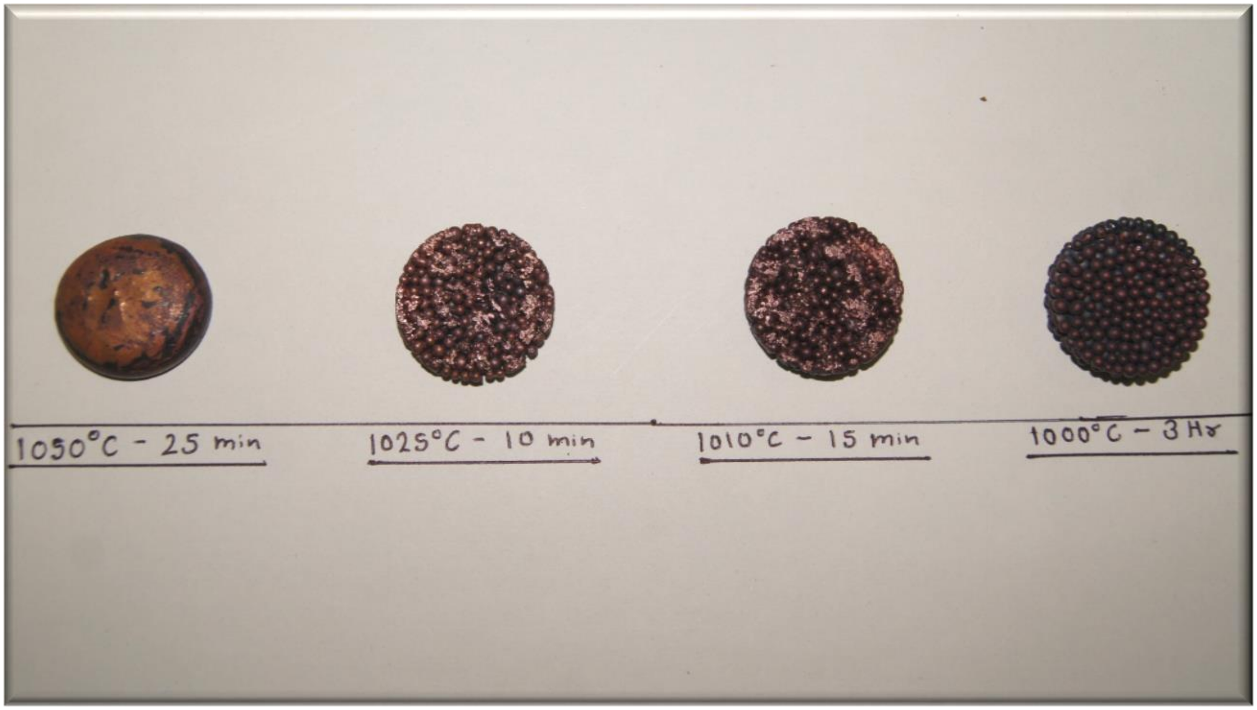


Figure 4 (sintered samples with no pressure applied)

Figure 5 (sample 1)

On the temperature 1050°c for 25 minutes copper start melting, it didn’t melt completely because on examine the sample closely some of the copper ball shapes were present in the solidified sample.

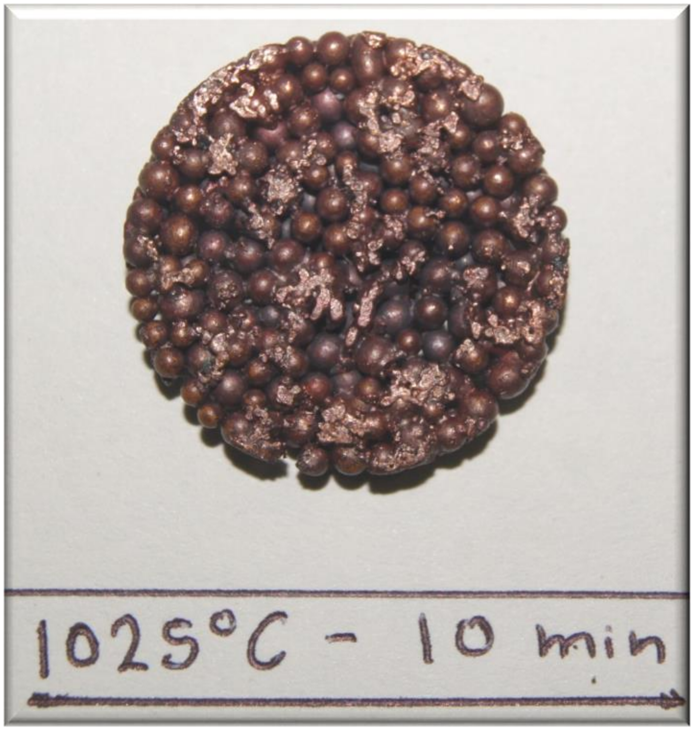


Figure 6 (sample 2)

At the temperature 1025°c for 10 minutes, copper balls start making bond with each other but the bonds were improper, it happened because only the side which were in contact to mold gets sufficient temperature.

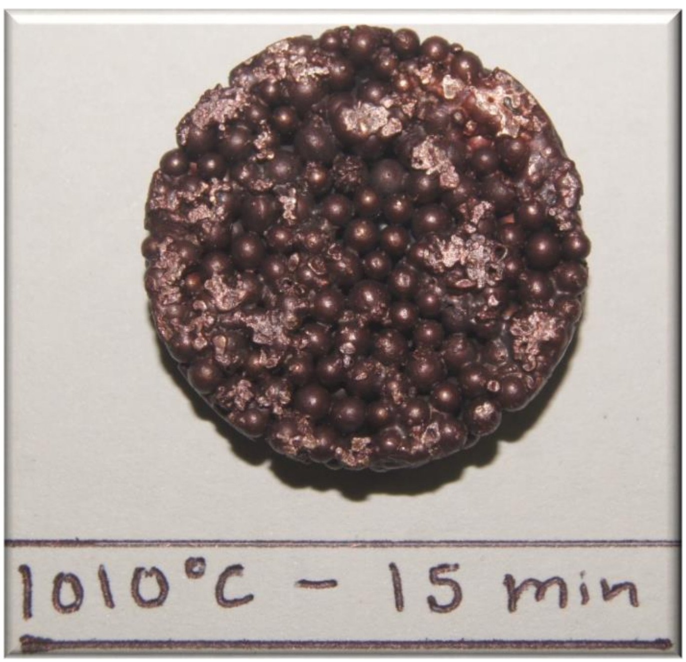


Figure 7 (sample 3)

At 1010 °c for 15 minutes, particles got much time for temperature distribution so in middle balls were also got bonded at some level but the bonding was very weak.

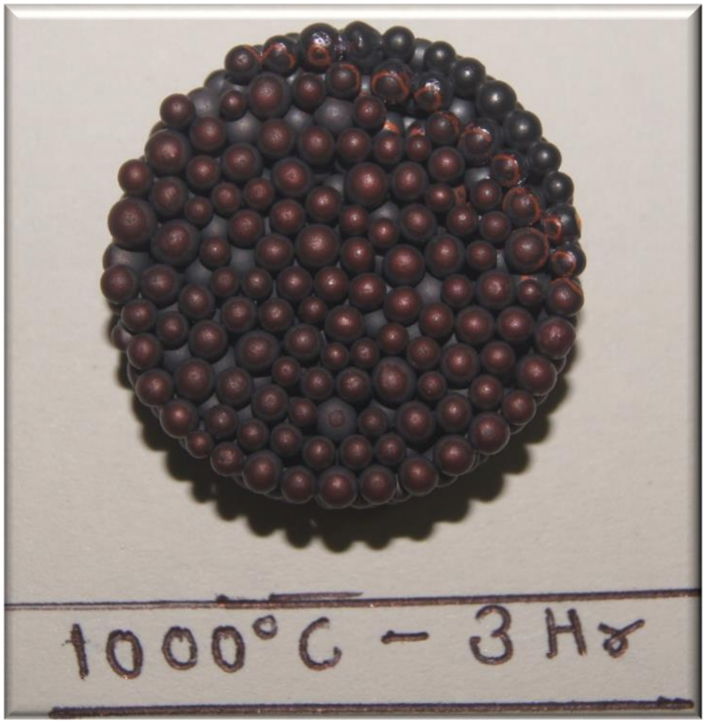


Figure 8 (sample 4)

At 1000°c for 3 hours, copper surface have copper oxidation layer, which cause not to make bond balls to each other, this happened because copper got sufficient amount of time to oxidize and the temperature was also less because we were not applying ant kind of pressure to the sample. Oxidation layer of copper can be seen in (figure 9). So from these experiments we got to know that we need to use some flux to stop the oxidation. And also we need to make apply little pressure so that each particle stick to each other with no gap of separation so that no oxidation layer can form in between the particles. We need to make a little mechanical press, which can apply sufficient amount of pressure within the muffle furnace.

Figure 9 (oxidation layer present in sample 4)

CHAPTER 4 (FUTURE SCOPE OF THE PROJECT)

The burning issue for now a days in industries is that industries are not being able to produce as much components as much they are required by market, cause it consume a lot of time to produce parts and for EDM it is the most time taking process cause for EDM operation we need to lift up the tool again and again to remove the melt. So by making a porous electrode of most suitable porous structure we can reduce the lift up time of electrode, and it will increase the production of EDM machined part. So in future where we need rough finished and semi-finished part, we can use this type of porous electrode instead of the solid one.

A. Can be used for roughing where more MRR required.
B. Can be used where the symmetric geometry is desired.
C. It will consume less time so it can compete the product requirements with old production methods.

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