Analysis of ECM Electrode and ECM Electrolyte for Machining Of Star Shaped Complex Profile over Iron Work Piece Using ANSYS Fluent Software

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***Abstract*- ECM (Electrochemical Machining) is used for machining of very hard material and complex geometry. ECM is used where there is high machining accuracy is required such As Die Sinking Operation, 3D Profiling Operation, Micro Drilling Operation. ECM is non-conventional type of machining process which is based on reversed electroplating phenomenon in which Anodic dissolution (work piece) occurs in electrolytic medium such as NaCl and NaOH solution. For machining of Iron work piece generally copper or tungsten is used as electrode while NaCl or NaOH is used as electrolyte. Using ANSYS Fluent software analysis is done over copper electrode, tungsten electrode, NaCl electrolyte and NaOH electrolyte. Based on electrical, thermal and kinetic analysis it's found that copper as electrode and NaCl as electrolyte is the best choice for machining of iron work piece.**

***Index Terms*- ECM, Electrochemical Machining, Reverse Electroplating, Electrode, Electrolyte, ANSYS Fluent, Micromachining, Non-conventional machining. Complex profile machining**

I. INTRODUCTION

ECM is non-conventional machining based on the principle of reverse electroplating. Cathode is electrode tool and the Anode is work piece. The exact mirror image of cathode tool machining surface is printed on work piece. The Cathode and Anode are applied to low voltage and high current power source and both electrodes are immersed in electrolytic solution. On anode (work piece) there is atomic level material removal occurs due to electrolysis process whereas on cathode electrode tool only H_2 Gas evolution takes place. This reaction shows that negligible tool wear is occurring on cathode tool. In ECM process material removal rate is proportional to the only current flowing through electrode and it's not dependent on the hardness of material. Therefore even very hard material can be machined without undergoing thermal and mechanical stresses.

In ECM process Copper, Tungsten, Brass, Graphite and Copper-Tungsten alloys are used as cathode electrode tool. And generally natural salts with 40% concentration are used as electrolyte solution for example NaCl, NaOH or HCl.

In this paper I have presented Analysis of ECM process for complex shape machining on iron work piece using ANSYS Fluent software. Out of copper and tungsten electrode the best electrode is selected for machining of iron work piece. And out of NaCL and NaOH best electrolyte is selected for machining of iron work piece based on the result obtained from ANSYS Fluent post processing.

In ANSYS the experimental boundary conditions are fed to ECM process then current density profiles, turbulence profiles, Temperature profiles are obtained in ANSYS post processing results.

Electrolyte and Electrode with best result will be accepted for electrochemical machining. For simplicity of analysis the ECM setup is considered as combination of two models.

1) Electrode model
2) Electrolyte model

II. ELECTRODE MODEL

The tool shape generated in the design module of ANSYS 16.0 is as shown in the figure 1.

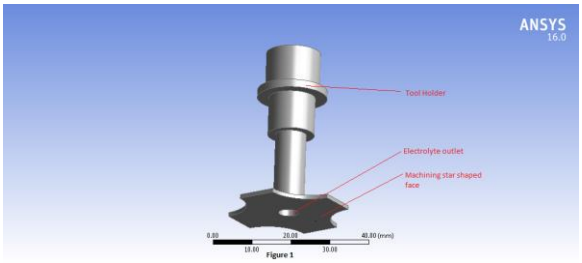

Figure 1

The shape of tool is circular in cross section. Special provision is made to hold tool in servo motor feed

mechanism. The tool is feed with constant feed rate to iron work piece. The gap between the tool machining face and upper surface is kept as 0.05 mm. Throughout 3 mm hole is made in the tool for supply of electrolyte. Which enters in tool from top and then it will flow between the upper surface of work piece and machining face of tool.

Dimensions of Cathode tool are as follows:

The total height of ECM tool = 60 mm
The holder diameter = 12 mm
The tool holder collar diameter = 30 mm
Thickness of machining face = 1 cm

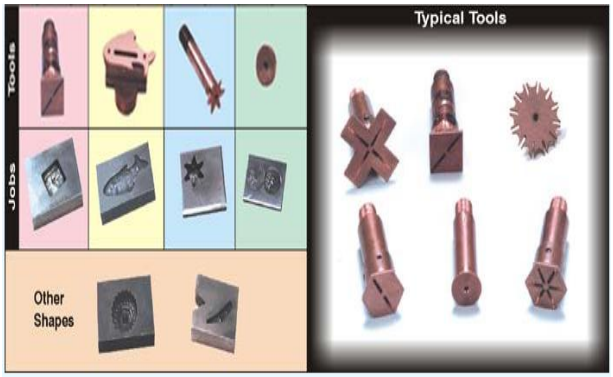

Figure 2: some actual Tools and their machined job

Cathode Tool Material Properties at 25°C

In simulation of electrode two cathode electrodes are compared. These two electrodes are as follows.

1) Cathode
2) Tungsten

Table 1: Copper and Tungsten Properties

Molar mass(g/mol)	63.546	183.84
Density(Kg/m3)	8940	19600
Specific heat(J/KgK)	385	132
Thermal Conductivity(W/mK)	401	174
Electrical Conductivity(S/m)	5.96×10^7	1.79×10^7
Price (Rs/Kg)	500-700	4000-5000

III. BOUNDARY CONDITIONS

Low voltage of 30 V is applied to the cathode electrode. So that the 10000A current is flowing through the ECM setup. Electric current enters in the hold of cathode tool then it goes to the machining face of tool. During jumping of electrons from machining face of tool to work piece through electrolyte electroplating reaction occurs which causes atomic layer removal of work piece.

Therefore boundary condition is considered as Voltage=30 V, Current=10000

First copper electrode is simulated and then tungsten electrode is simulated with the same boundary conditions mentioned in above.

IV. RESULTS TOOL MODEL

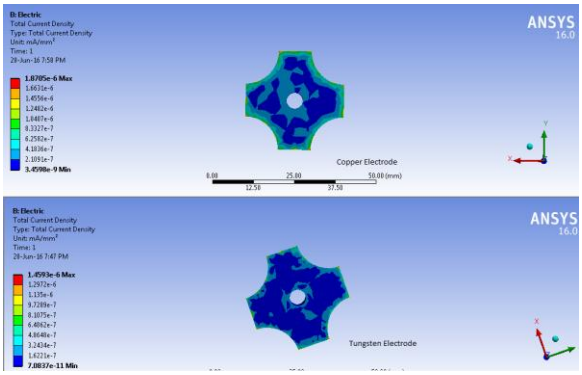

Figure 3: current density contours on cathode tool and tungsten tool

In the above results the copper shows more uniform current density. Whereas Tungsten electrode shows lesser uniform current density. Because copper is good in electrical conductivity than tungsten. The current density is more near edges of tool because of Skinny effect. Skinny effect states that current flowing through connector will cases more resistance in the core of conductor that's why current prefers to flow on the skin of conductor that's why current density is more on corners of electrode.

V. ELECTROLYTE MODEL

The complete set up for ECM simulation will look like as in figure 4. Between the machining face and work piece very small gap is kept. This gap is called as Inter Electrode Gap. Inter electrode gap in this simulation is 0.05 mm. continuously electrolyte is flowing through this gap. The electrolyte enters in machining zone with velocity of 45 m/s and comes

out with work piece sludge passing through inter electrode gap.

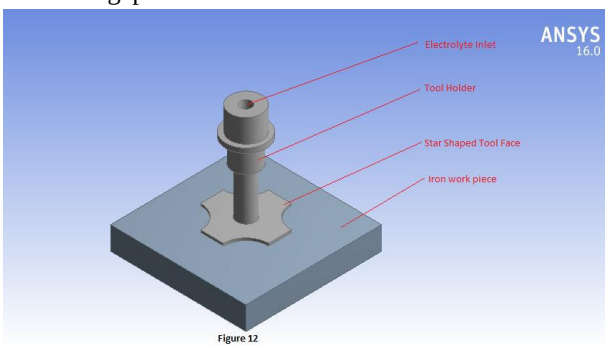

Figure 4: ECM Setup

Moto of electrolyte simulation model is to study the flow of different electrolytes i.e. NaCl and NaOH over the iron work piece. So we will concentrate only on inter electrode gap. For study purpose the ECM setup model is reduced in simple geometry. As shown in below diagram.

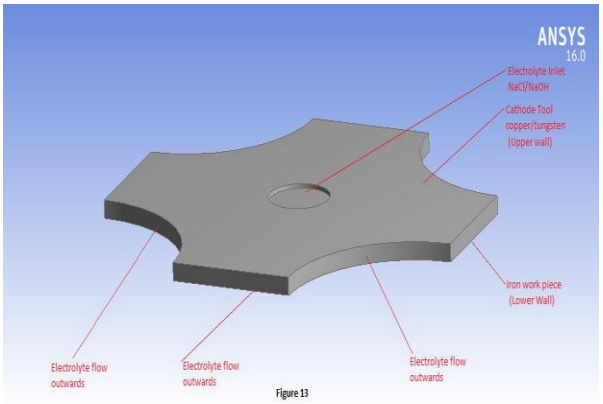

Figure 5: Electrolyte Model

The upper wall is cathode electrode made up of copper/tungsten. All properties of electrode will be applied to this wall type boundary condition. Such as conductive heat transfer. Convective heat transfer, temperature of wall, electric conductivity and density.

The lower wall is the iron work piece.

The star shaped complex profile is to be machined on this iron work piece. All properties of iron will be applied to this wall type boundary condition. Such as conductive heat transfer, Convective heat transfer, temperature of wall, electric conductivity and density.

Now the electrolyte is considered to be entering through 3 mm diametric hole and then flows in between the top face of cathode electrode tool and upper face of work piece. Finally electrolyte with machined sludge comes out through side openings.

Table 2: Electrolyte Properties With 40% concentration at 100° C

Property	NaCl	NaOH
Density (Kg/m^3)	1050	1405
Specific heat at constant Pressure Cp (J/Kgk)	3760	3471
Thermal Conductivity (w/mk)	0.6	0.688
Viscosity (Kg/ms)	0.001	0.008

Before doing the analysis, the material properties of all the three materials of tool, work-piece and brine are imposed on simulation model.

VI. RESULTS OF ELECTROLYTE MODEL

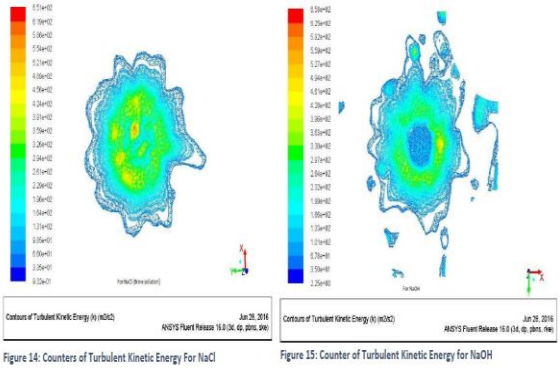

Figure 6: Turbulent Profile for NaCl and NaOH

Uniform and more turbulence flow is found in the NaCl electrolyte whereas non uniform and less turbulent flow is found in NaOH electrolyte. This is because NaCl is having less viscosity than NaOH. NaOH produces more H_2 evolution during machining because of OH^-ions present in Electrolyte. Which causes more H_2 gas evolution this leads to cavities into the flow of electrolyte.

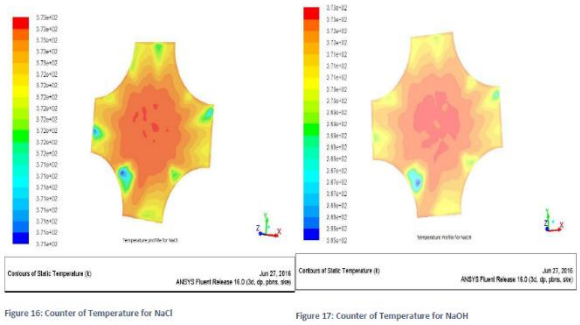

Figure 7: Temperature profile for NaCl and NaOH

In case of NaOH the high temperature concentration in the center is more as compare to the center of NaCl work piece. Since specific heat of NaOH is lesser than the specific heat of NaOH. Also another reason is that the heat dissipation in case of NaOH is less due to less turbulence of electrolyte.

VII. CONCLUSION

1) In case of machining of iron work piece it's better to use copper electrode since it shows uniform current density over the machining face of tool. Whereas Tungsten shows lesser Uniform current density since the skinny effect is more dominant in tungsten electrode.
2) In case of machining of iron work piece it's better to use NaCl as electrolyte because:

    a. NaCl gives good turbulent profile than NaOH turbulent turbulence profile. Because more is turbulence more will be ability of electrolyte to carry away sludge from machining zone.In NaOH H_2 gas evolves more during machining of Iron work piece which causes cavities in the electrolyte.
    b. On comparing the temperature profile its observed that temperature concentration is more in the center of iron work piece in case of NaOH electrolyte. Which may lead to cause minor thermal deformation of work piece. So it's recommended to use NaCl electrolyte for machining of Iron work piece in ECM.

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