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Electrolyte Flow Analysis of Electrochemical Machining Using CFD

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ABSTRACT

Electrochemical machining is one of the most common unconventional machining process which is mostly used for machining extremely hard materials.In electrochemical machining process tool is taken as cathode and workpiece is taken as anode.An electrolyte of reactive manner is made to flow over tool and workpiece .This electrolyte tends to undergo boiling and passivation because of heat generated during machining.This project aims to design the machine setup by taking four different tools.The project is designed in ansys modeller and then analysed in ANSYS CFX to get results.So that we can decide which tool shape is best for machining in electrochemical machining process.

KEYWORDS: Electrochemical machining, Passivation, Ansys.

1. INTRODUCTION

Electrochemical machiningprocess is a type machining processin which a voltage applied between two electrodes. The tool and workpiece are always arranged such that there is a gap exists between them.The electrolyte flows in this gap and because of the heat generated during the machining electrolyte boils and causes passivation effect which causes defects in the final shape of workpiece and marks out to be a defect.The electrolytes typically that are used in electrochemical machining are Hcl, Strong alkaline solutions,Nacl etc.The electrolyte that we are using is 30% brine solution and the workpiece shape is taken as cylindrical with the material of Cast Iron and tool is considered to made with copper and four different shapes are taken in for analysis. First the machine setup is designed in ansys design modeller and then analysed in ANSYS CFX software. The inlet velocities that are taken as input are 30,37 and 42m/s.

STRUCTURE OF PAPER

The paper is organized as follows: In Section 1, the introduction of the paper is provided along with the structure, objectives and related work. In Section 2, materials and methodology are defined. In Section 3, we discussed modelling and analysis.Section 4 shares information about the results that have obtained. Section 5 gives the conclusions that are concluded from the work. Section 6 tells us about the future scope and concludes the paper with references.

1.1 OBJECTIVES

In case of intricateworkpieces, it's really hard to the machinine the components accurately. So there is a needto understand about those parameters (parameters related to flow pattern). Once the flow patternis known, then it's easy to design the tool and avoid passivation.

With this background the salient objectives are stated below:

To study the electrolyte flow and optimize the designed models of tools.

To evaluate different tools for better machining and to determine inlet velocities.

1.2 RELATED WORK

Marius Purcar *et al.* (2004) [1] discussed about 3D electrochemical machining computer simulationbased on marker method. This method related with the instantaneous change of tool shape.MostrecentlydevelopedBEMsoftwaretomodel3 DECMprocess.Trialand error method are using for predicting the workpiece shape. Some analytical models are usedfor this.

Kozak *et al.* (1998) [2] discussed about the computer simulation electrochemical shapingusing a universal tool electrode; its application is limited in Flexible Manufacturing System. Inthis paper universal electrode tool for avoiding the difficulties in ECM and the final shape of theworkpiece is obtained by controlling the motion of tool. This study is to avoid the usage of high-costelectrodeswith complicatedshapes.

Kozak(1998)*et al.* [3]proposedaMathematicalmodelforcomputersimulationofelectrochemicalmachining process. Software for the ECM process was developed in Warsaw University ofTechnology covered the basic manufacturing problems in ECM. This software includes FDM,FEM, and BEM techniques for solvingthe problem. In this paper the Physical and Mathematicalmodelbasedonsimulationmodulearepresented.

LDabrowskiandTPaczkowski*et al.* (2011)[5] publishedpaperrelatedtothetwo-dimensionalelectrolyte flows in ECM. They used vibrating type tool for machining. They found out that theusage of vibrating tool helped to increase accuracy and stability of machining. During machiningtheIEGalterfromminimumtomaximumaccordingtothecurrentdensity.Thephysicalphenomena in IEG are described by using differential equation and partial derivatives. Shape ofthe workpiece is altered due to non-uniform rate of anodic dissolution. Temperature distributionintheIEGwithaconstantfeeddependsupont hehydrodynamicconditions.Theyconcludedthatat lower vibration frequenciescalculated results aremore accurate.

GuilanWang*etal*.(2007)*et al.* [6]publishanarticleabout3-Dmodelofthermo-fluidandelectrochemicalfor planar SOFC.They solvedThermofluidmodelusing ANSYS-CFX.

1. MATERIALS AND METHODOLOGY

Materials used for making this simulation are, Iron as workpiece, Copper as tool and 30% brinesolutions as electrolyte.Data is referred from [7] and [4].

Table 1: Material Properties

Properties	Brine	Copper	Grey cast iron	Air
Molarmass (Kg/Kmol)	57.44	64.55	56.85	-
Density(Kg/m^3)	1050	8933	7866	-
Specificheat(j/KgK)	3760	385	460	-
Dynamicviscosity (pas)	0.001	-	-	-
Thermal Conductivity(W/mK)	0.6	401	80	-
Electrical conductivity (S/m)	8.43	5.96E+07	1E+07	-
Convection coefficient (W/ m^{3}K)	1000	-	-	100

2.1 Methodology

The methodology workedout to achieve the mentioned objectives is as follow:

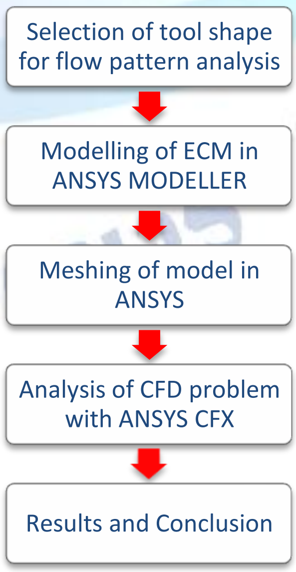

Figure 1: Flow chart of methodology

3. MODELLING AND ANALYSIS

3.1 Design of ECM setup in ANSYSmodeller:

ECMconsists of a workpiece, tool and an electrolyte solution. Workpiece should be a conducting material of electricity and can be or cannot be. Commonly used electrolytes are NaCl solution and $NaNO_3$. To get required shape in the workpiece the tool should be designed accurately. Here we have considered four models and designed them. These different models are mentioned below:

Model 1-Tool with central through hole.

Model 2- Tool having slot in the tool face with rounded corners.

Model3-Tool having intermediate chamber and slot in the face with rounded corners.

Model 4-Tool having slot in the tool face with Sharp corners.

The initial shape of the workpiece in all models is same. It is circular in shape with 60 mmdiameterand20mmheight.Modelofworkpieceisshown inFigure1.ElectrolyteusedforthissimulationwasNaCl solution.Itstartsflowingfrominlethasaconstantdiameter of3mm. All models are analysed with three different inlet velocities 30 m/s, 37m/s and 42 m/s. Thesevelocities are fixed with respect to the flow rate limit(15-20 L/min) of the flow without passivationintheECM process. Tool outer dimensions arealso kept as constant and shown in Figure-1.

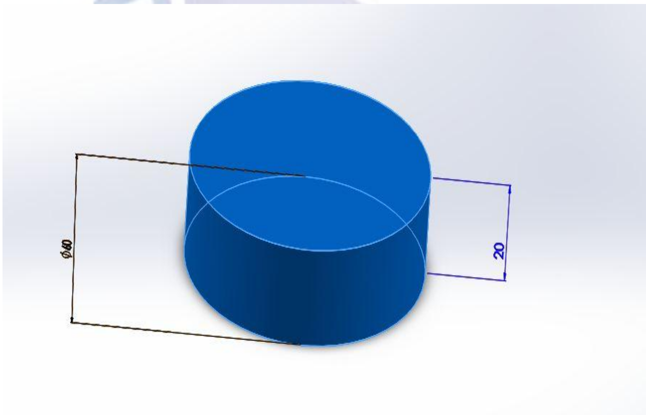

Figure 2:Shapeofworkpieceusedforsimulation

Inter electrode gap for all models:

The inter electrode gap (IEG) for all models is taken as 0.5 mm and drawn the same in modeller as shown in Figure-2.

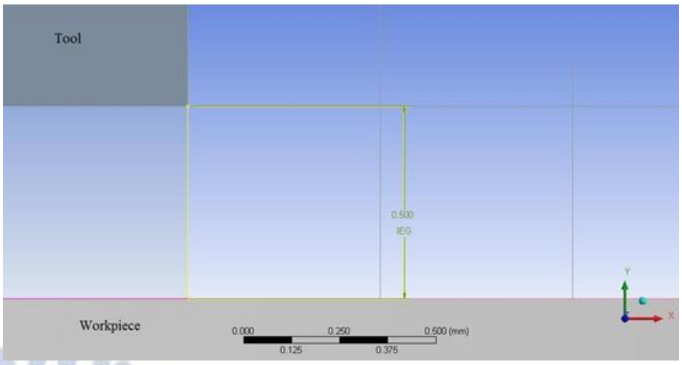

Figure 3:Inter electrode gap for all models

3.2 Model1–LShapedToolwithCentralThroughHole

Model 1 is a simple L shaped model having a central through hole with a diameter of 3mm andheight 50 mm. This centre of the hole is fixed on (-7.5,-7.5) coordinate in the XZ plane. Fluid isflowing through the through hole and flow out through the IEG.

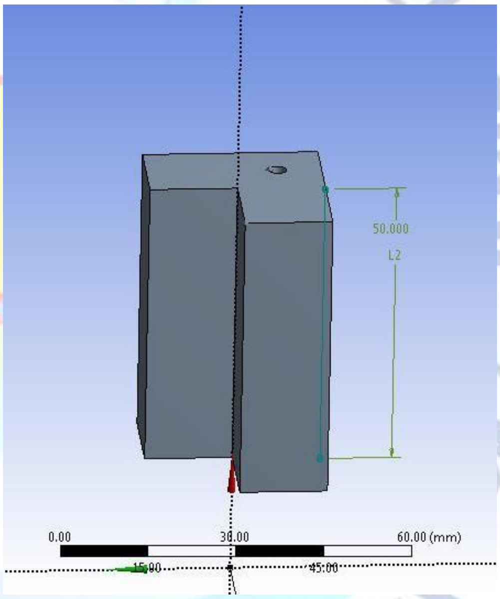

Figure4:Tool dimensions formodel 1

3.3 Model 2- L Shaped Tool Having Slot In The Tool Face With Rounded Corners

DifferenceofModel2fromModel1isthatthebottomsfaceofthetoolhavinggrooveswithroundedcorners.Inthismodelthecentralholehas3mmdiameterandtwogroovesareconnectedwiththisasshownintheFigure4Thosegroovesare havingadiameterof0.8mmandendcornersofthegrooves withadiameterof3mm. distancebetweenslotendandcornersofworkpiecewantto keepatleast1.5mmandthewidth of theslots are0.8mm forbest results.

Theseconditions are takeninto accountforall tooldesigns.

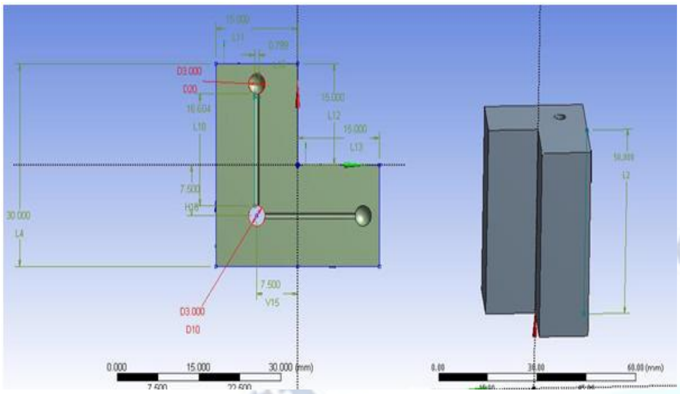

Figure5:Tooldimensions for Model 2

3.4 Model 3L Shaped Tool Having intermediate chamber and Slot in The Tool Face With Rounded Corners

Model 3 is entirely different from other models. In other models fluid is coming from the inletand distributed to the grooves at bottom face of the tool. In Model 3 fluid is first come to the L-shapedchamberthenitflowstotheIEGthroughslotsprovidedinthebottomofthetool and shown in the Figure 5.

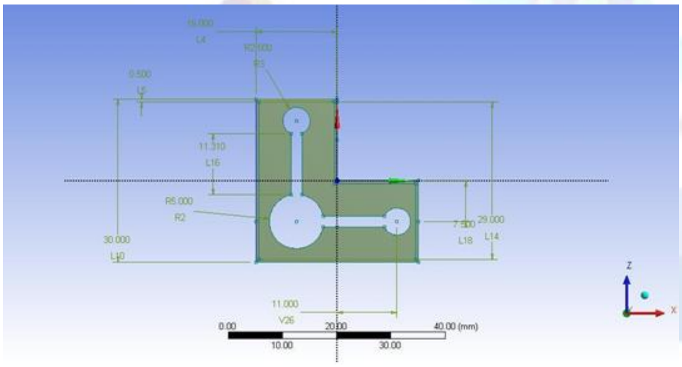

Figure6:Tooldimensions for Model 3

3.5 Model 4 - L Shaped Tool Having Slot In The Tool Face With Sharp Corners

This model is almost same as that of Model 2. The only difference in this model is sharp endedslots. Dimensions of the slots are shown in Figure 6. It consists of a small circular end with adiameter0.8 mmand height of 50 mm.

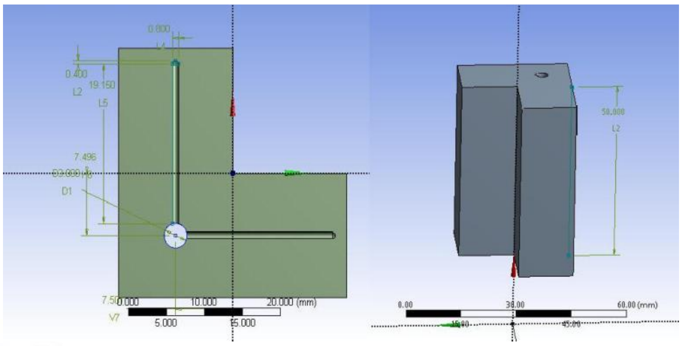

Figure7:Tooldimensions for Model 4

3.6 MESHING

Models are meshed using ANSYS Mesh Module in ANSYS commercial software. The quality ofmesh is relevant in the case of model geometry and results accuracy.Table 2 shows the meshing properties for all the models.

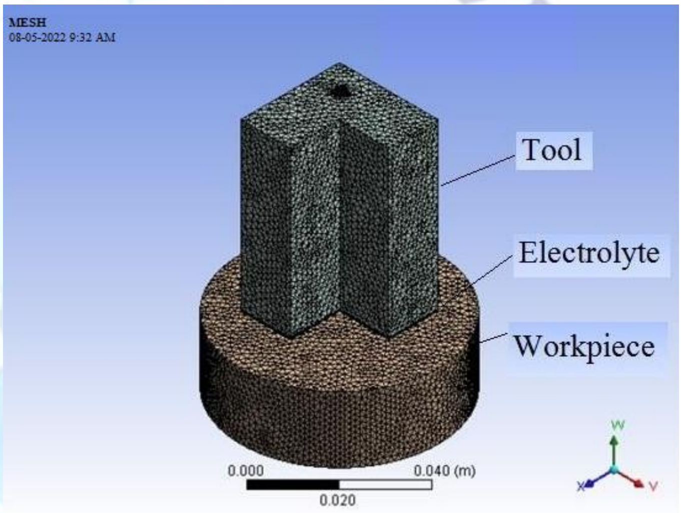

Figure8:Outershapeof meshed model forModels 1,2 and 4

Table 2: Meshing Properties

Model	Nodes	Elements	Skewness	Orthogonal quality
1	3320377	2392617	0.640137	0.9878
2	341842	625685	0.893000	0.9960
3	500050	2597095	0.84000	0.9994
4	344130	637849	0.86000	0.9980

4. RESULTS

Velocity, turbulent kinetic energy,shape change of work piece and MRR with respect to inlet velocity are discussed for the fourdifferentmodelsgeneratedusingthe commercialsoftware ANSYS 16.2.

4.1 EFFECTONVELOCITYPROFILE

Figures 8 and 9 are the velocity profiles within the IEG of the models (Model 1, 2, 3and 4) used for the stimulation.

The velocity profiles are plotted for the range = 0 to 30 m/s forthepresent studyof thespecimens.

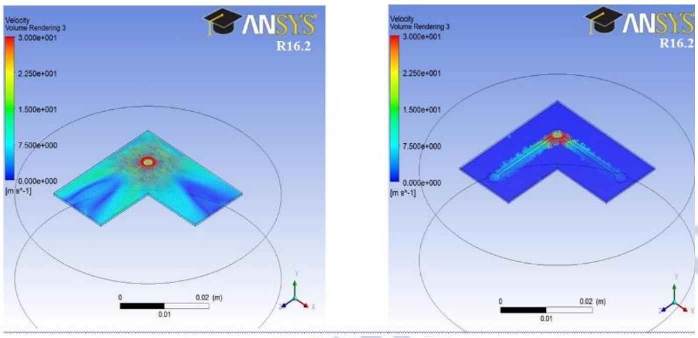

Figure9:VelocityprofileofModel1 and model 2with an inlet velocity30m/s.

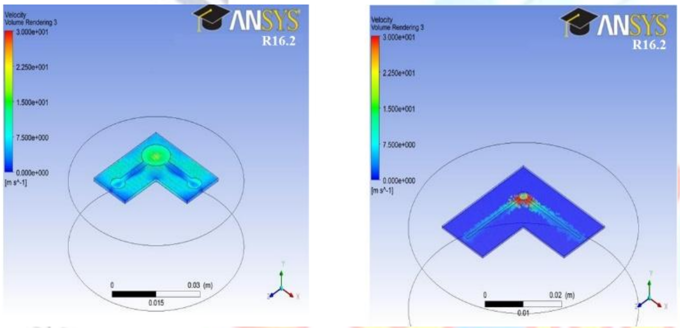

Figure10:VelocityprofileofModel3 and model 4with an inlet velocity30m/s .

Thevelocity distributionsareshown in Fig 10for inlet velocity = 37 and 42 m/s, respectively. From these figures, itcanbeconcluded that passivation tendencydecreasingwithincreasinginlet velocity.Among these four models, Model 3 is the best in the sense of velocity profile. Hence, extendedsimulationofModel3withhighervelocitieswasconducted.

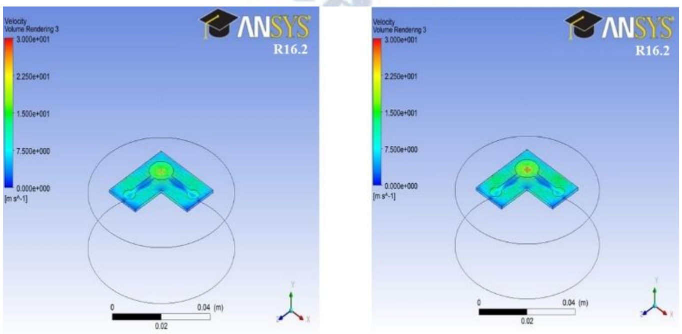

Figure 11:VelocityprofileofModel3 atinlet velocities of37m/s and 42m/s.

4.2 EFFECTONSTREAMLINE

Thestreamlines aregenerallyrepresenting the velocityflowpatternin a fluid flow. Figs. 11and12arethebottomviewofthe3Dstreamlinepatternfor Model1,2,3and 4,respectively.

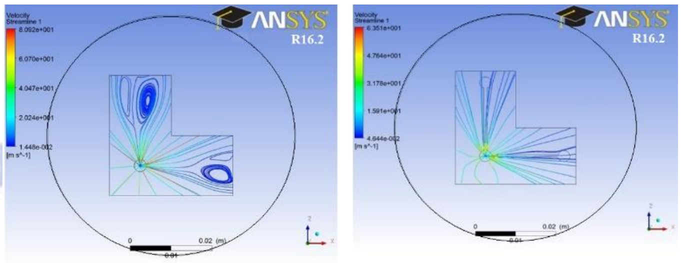

Figure 12:Stream line flow ofModel1 and model 2with an inlet velocity30m/s.

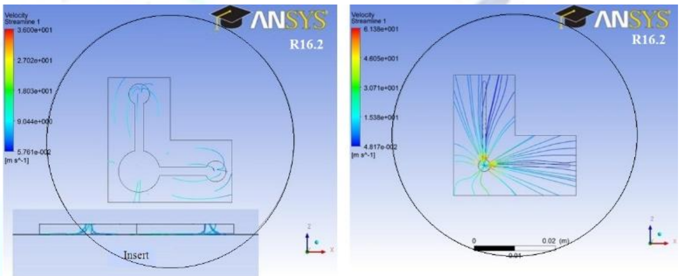

Figure 13:Stream line flow ofModel3 and model 4with an inlet velocity30m/s.

From the figures, it can be understood that there is eddy formation in the flow pattern in the endregion of the 'L' and velocity in the eddy region is less than 5m/s.These defects cause passivation within the IEG. InFigure13, for Model 3, the streamlines are distributed in proper manner.From the above figures, it can be understood that Model 3 is the best, sowecontinuethesimulationofModel3withincreasinginlet velocities37m/sand4m/s.Those resultsareshowninFigure 14Intheseplots,thedistributionsofstreamlinesarealsosatisfactory.

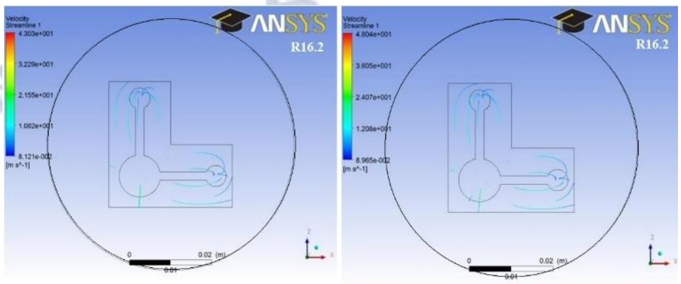

Figure 14:Stream line flow ofModel3 at 37m/s and 42m/s velocities.

4.3EFFECTONTURBULENTKINETICENERGY*(k)*

Figures.14and15aretheturbulencekineticenergywithinthe IEGforModels1,2,3 and 4, respectively, with an inlet velocity 36 m/s. Turbulence in the k- ε model is depends onturbulent kinetic energy (k) and turbulent eddy dissipation (ε).

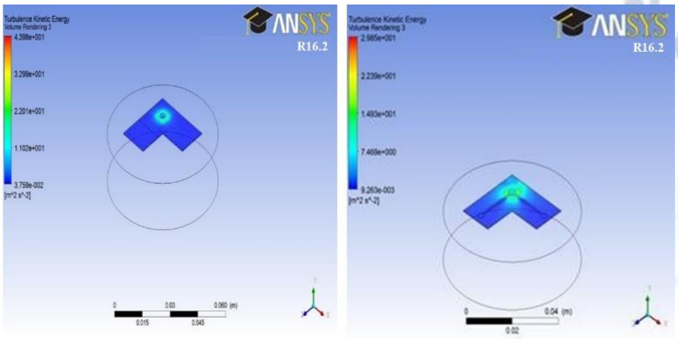

Figure 15:Turbulent kinetic energy ofModel1 and model 2with an inlet velocity30m/s.

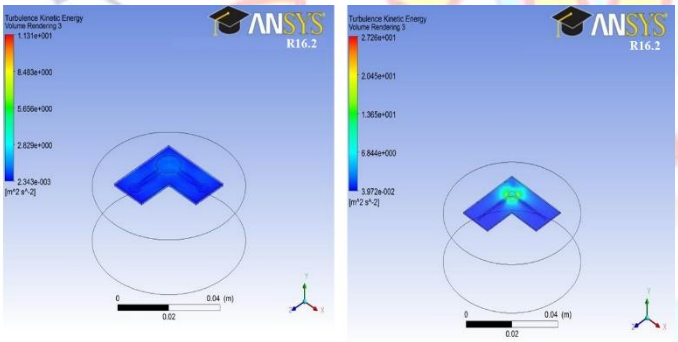

Figure 16:Turbulent kinetic energy ofModel3,4 with an inlet velocity37m/s.

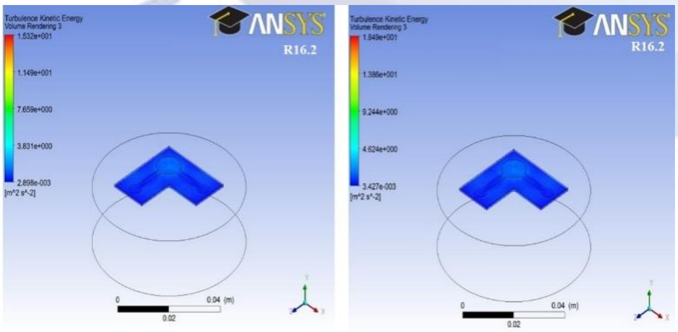

Figure 17:Turbulent kinetic energy ofModel3 at inlet velocities of 37m/s and 42m/s

It can be understood that Model 3 is the bestamong those models in the sense of turbulent kinetic energy because of the maximum andminimum'k'values areless.

4.5 EFFECTONTEMPERATURE

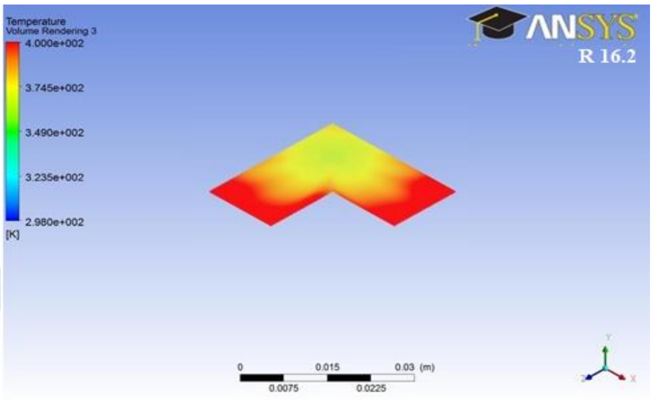

Figure 18:Temperature distribution for model 1 at 30m/s.

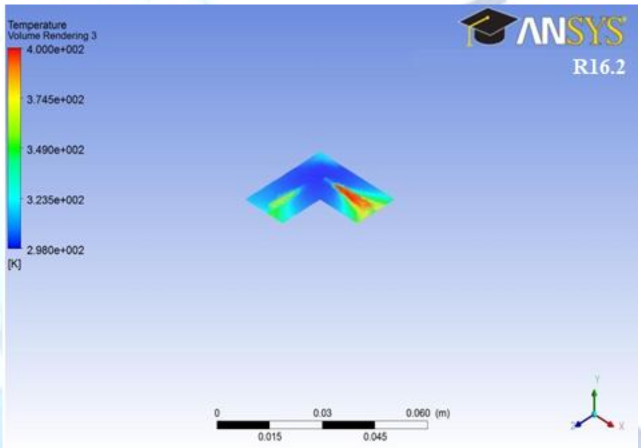

Figure19:Temperature distribution for model 2 at 30m/s.

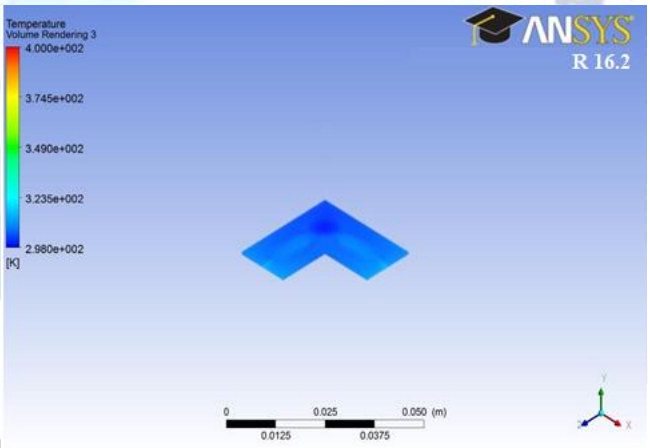

Figure20:Temperature distribution for model 3 at 30m/s.

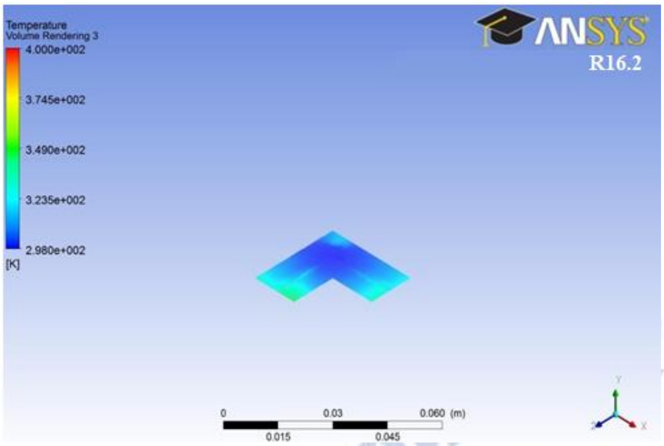

Figure 21:Temperature distribution for model 4 at 30m/s.

Figures. 17,18,19 and 20are the temperature distribution within the brine solution only inthe IEG for Models 1, 2, 3 and 4 with an inlet velocity of 36 m/s respectively.Distributionoftemperature with 43 and 48 m/s velocities are shown in Figure. 21 and 22 respectively. Fromtheseresults,itcanbe concluded thatmaximum temperatureobtainedinvariousmodelsshowdecreasingtrendwith increasinginletvelocity and can say that model 3 is best.

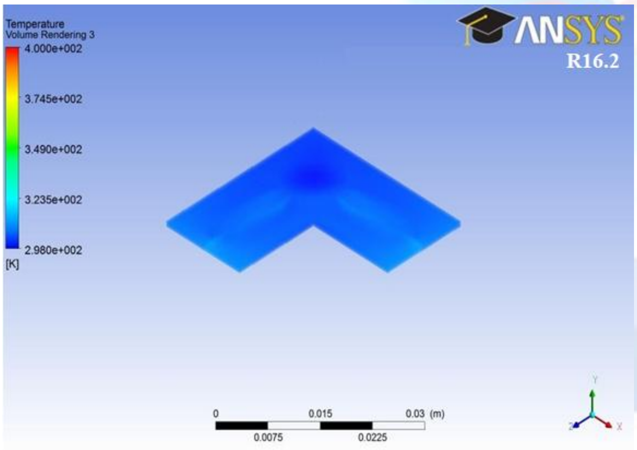

Figure 22:Temperature distribution for model 3 at 37m/s

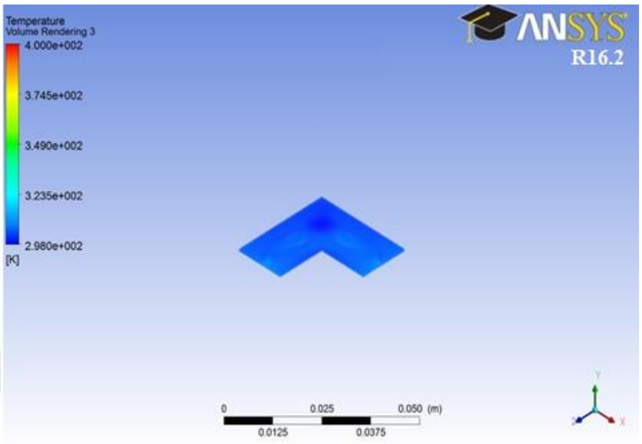

Figure 23:Temperature distribution for model 3 at 42m/s

4.7INFLUENCE ON FINAL SHAPE

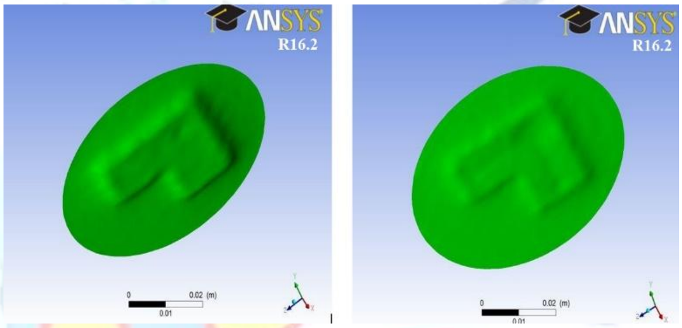

Figure 24: Work piece top surface after 30s of machining of model 1 and 2 at 30m/s inlet velocity.

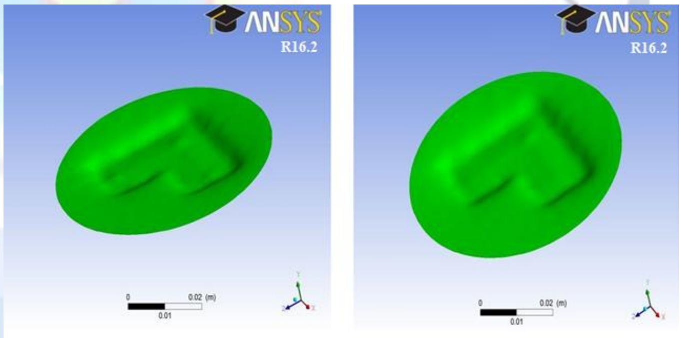

Figure 25: Work piece top surface after 30s of machining of model 3 and 4 at 30m/s inlet velocity.

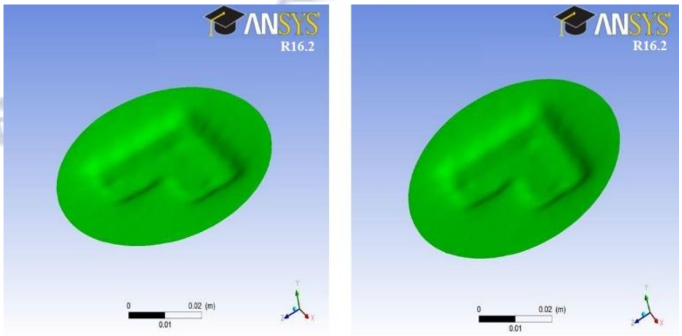

Figure26: Work piece top surface after 30s of machining of model 3 at 37m/s and 42m/s inlet velocities.

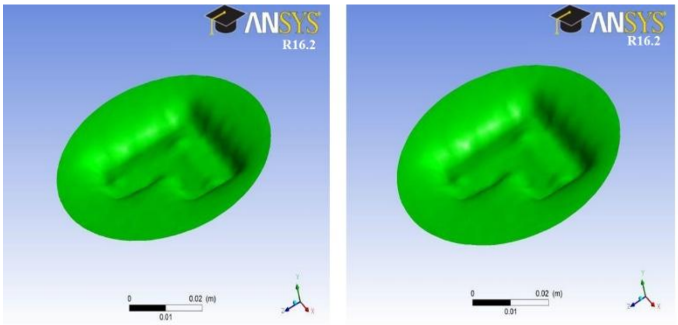

Figure27: Work piece top surface after 60s of machining of model 3 at 30m/s and 37m/s inlet velocities.

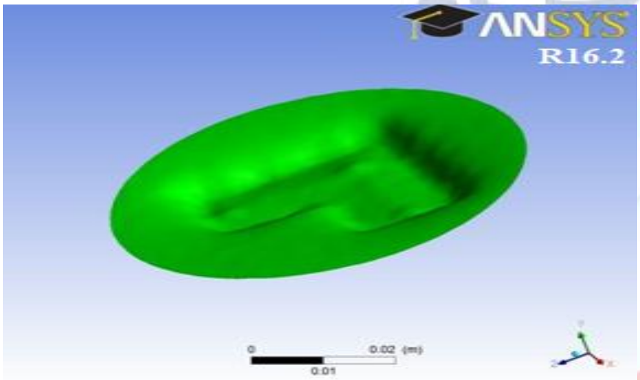

Figure28: Work piece top surface after 60s of machining of model 3 and 2 at 42m/s inlet velocity.

The final shape of the workpiece after 30s of machining with an inlet velocity 30 m/s for Models1,2,3 and 4are shown in Figures. 23 and 24. Figure 25 shows the Work piece top surface after 30s of machining of model 3 at 37m/s and 42m/s inlet velocities as well as Figure 26,27 shows the Work piece top surface after 60s of machining of model 3 at 30m/s,37m/s and 42m/s inlet velocities. From the results we can conclude that Materialremoval is the highest in case of Model 3.

4.8INFLUENCE ON MRR

Figure28 is the graph plotted MRR against inlet velocity for various models. For Model 1, theMRRismuchless thanthatofothermodelsforallvelocities.Thiscanbeattributedtopassivation effect when material removal from these areas is less. MRR is increasing from0.029×10^{-6} m^3/s to 0.0301×10^{-6} m^3/s and to 0.0305×10^{-6} m^3/s.

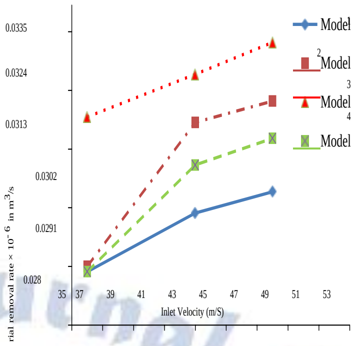

Figure29: MRR versus inlet velocities

From the graph it is understood that Model 3 hasmore MRR. Reason for that is uniformity in current density distribution and less passivation.MRR is increasefrom 0.0319×10^{-6}m^3/s to 0.0327×10^{-6}m^3/s and finallyto0.0333×10^{-6}m^3/s.

5. CONCLUSION

Electrolyte flow analysis of electrochemical machining process has given us a good idea of temperature profile,velocity distribution profile,streamline flow distribution,influence on final shape of the tool and material removal rate, which are essential machining parameters for ECM. In this simulation a copper tool,electrolyte of 30% brine and cylindrical iron workpiece are taken and all models are analysed with 30,37 and 42m/s inlet velocities. From the entire analysis we can say the model with intermediate chamber and slot in the face with rounded corners is best among all. Passivation decreases with increase in velocity. Material removal rate and turbulence increase with increase in velocities and the maximum temperature between tool and workpiece is decreasing with increase in velocity.

6. FUTURE SCOPE

The final shape obtained from this analysis can be used as inputs for next researchs and projects. We can implement the results obtained from this experiment in reality. Solid fluid interactions can also be added. Since we have done the analysis in steady state, analysis can also be extended to transient conditions.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Purcar, M., Bortels, L., Bossche and B.V.D. Deconinck, J., (2004). 3D electrochemical machining computer simulations, Journal of Materials Processing Technology, 149, 472–478.

[2] Kozak, J., Chuchro, M., Rusza, A. and Karbowsk, K., (2000). The computer aided simulation of electrochemical process with universal spherical electrodes when machining sculptured surface, Journal of Materials Processing Technology, 107, 283- 287.

[3] Kozak, J., (1998). Mathematical model for computer simulation of electrochemical machining processes, Journal of Material Processing Technology, 76, 170-175.

[4] Sian, S., (2011). CFD analysis of flow pattern in electrochemical machining, B.Tech. Project Report, National Institute of Technology Rourkela, Odhisa, India.

[5] Dabrowski, L., and Paczkowski, T., (2011). Computer simulation of Twodimensional Electrolyte flow in Electrochemical Machining. Russian journal of electrochemistry, 41,102–110.

[6] Wang, G., Yang, Y., Zhang, H and Xia W., (2007). 3-D model of thermo-fluid and electrochemical for planar SOFC, Journal of Power Sources, 167, 398–405V.

[7] Mcclesky, R.B., (2011). Electrical Conductivity of Electrolytes Found In Natural Waters from (5 to 90) °C. Journal of Chemical and Engineering data, 56, 317-327