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Design & Development of Electrode for Ultrasonic Assisted Pulse Electro-Chemical Machining

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ABSTRACT: This paper deals with various methodologies adopted by present researcher for Design and analysis of Pulse Electrochemical machining tool, with main objective of analysis and optimization of the tool. This review will assist researchers working in the field of development of the structural design of Electrochemical machining tooloptimization methods conducted by FEA software and for modelling CAD software viz. Solidwork 14.0 and Ansys Workbench 17.0. The review includes key areas of researches Harmonic Analysis, Modal analysis and CFD analysis using FEA. This paper progressively discusses about the research methodology, software and the outcomes of the discussed researches and is intended to give the readers a brief variety of the researches carried out on the design & development of electrode for ultrasonic assisted pulse electro-chemical machining.

Keywords: *Pulse Electrochemical machining, ECM, Ultrasonic Vibration, ANSYS analysis, Optimized tool design, CFD, Material Removal Rate, Modal Analysis*

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1. INTRODUCTION

Electrochemical machining is one of the most potential non conventional machining techniques used to machine high strength, heat resistant materials which are difficult to be machined by conventional technique into complex shapes. This process may be considered a reverse of electroplating, which is based on the principal of electrolysis. It is an electrochemical process in which two electrodes are used; work piece acts as an anode and tool as a cathode. It is also known as an anodic process as material removal is from the anodeon basis of principle it is similar to electrical discharge machining (EDM) except for there is no contact between tool and work piece at the time of machining which results in no tool wear as in case of EDM. In recent years, ECM has been widely used in the automobile industries, turbo-machinery aerospace, aeronautics, defence and medical industries because of its various

Advantages like negligible tool wear, complicated machining, life is more as compare to other tool used for machining and low stress in tool body. Though there are few disadvantages, such as bubble generation and its effect on Material Removal Rate, complex of tool geometry and its effect on various processparameters, prediction of electrolyte flow pattern and its impact etc which have been investigated by various researchers. Fluid (electrolyte), and a conductive workpiece (anode); however, in ECM there is no tool wear.[1] The ECM cutting tool is guided along the desired path.

2. Electrochemical Machining Set Up

In Electrochemical Machining (ECM), a high current, low voltage DC power supply connects a conducting tool and work piece. The shaped tool is connected to the negative terminal and work piece to the positive which are cathode and anode respectively. A conducting electrolyte flows through a small gap that is maintained between the tool and work piece, thus providing the necessary path for electrolysis. As the direction of electron flow is from work piece 2 to the tool, material removal is from the work piece in a reverse image of the tool. The several components of ECM setup as shown.

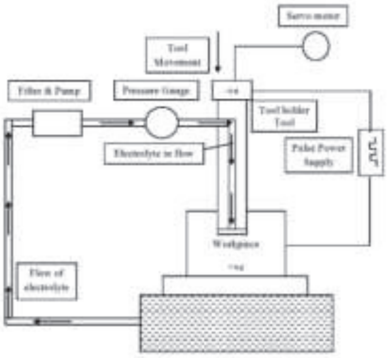

Fig. 2.1 Schematic diagram of various part of ECM setup

2.1 Work Piece

In electrochemical machining, work-piece is a conducting material which acts as an anode. It is connected to the positive terminal of the pulse power supply. The selective anodic dissolution will remove the material from the work-piece in the presence of pressurized electrolyte between the electrodes in a pre-set temperature. Generally materials with very high value of hardness or a very low value of machinability are used as work-piece materials in ECM as it removes material independent of the hardness.

2.2 Tool

Tool material used for electrochemical machining should have following properties: (i) good electrical and thermal conductivity, (ii) easy machinability, (iii) resistance to chemicals, (iv) good stiffness and (v) easily obtainable. Zero tool wear gives ECM upper hand over other machining techniques. Tool design is still largely empirical and must allow for an overcut of 0.020 - 0.70 mm over all active surfaces. Tool must be designed to provide for proper electrolyte flow through the gap. If area of stagnation occurs, surface finish will be poor and striation or ridges may be produced on the work-piece surface. As the tool is given a downward motion during machining, the work-piece tends to take the shape of the tool. The most commonly used tool materials are copper, brass, SS etc.

2.3 Electrolyte

Electrolyte is a conducting fluid which plays a very vital role in electrochemical machining. An electrolyte in electrochemical machining performs three basic functions:

1. It completes electrical circuit allowing the passage of current (i.e. acts as a conductor),
2. sustains the required electrochemical reactions,
3. Acts as a coolant and carries away the waste products.

Electrolytes can be categorized as: (i) Those composed of inorganic salts that produce insoluble by-products (known as sludging electrolytes), e.g. sodium chloride, potassium chloride, sodium nitrate and sodium chlorate, and (ii) Those composed of acids or alkalis that result in byproducts that do go into solution(known as non- sludging electrolytes) like sodium hydroxide and sulphuric acid. The selection of the electrolyte is based upon the work-piece material, the tool material and the application. Also, it must have a good chemical stability. Apart from these, it should be inexpensive, safe, and as non corrosive as possible. Generally, an aqueous solution of the inorganic compound is used. Table 1.1 lists the electrolytes used for various types of alloys.

Alloy	Electrolytes
Iron based	based Chloride solution in water (mostly 20% NaCl)
Ni based	HCl or mixture of brine and H_2SO_4
Ti based	10% hydrofluoric acid + 10% HCl + 10%HNO_3
Co-Cr-W based	NaCl
WC based	Strong alkaline solutions

Table 2.1Types of electrolytes

3. CAD Model

Modeling is done in Solidworks 14.0 software with the following geometry dimensions:

- length of the electrode = 70mm
- Outlet Diameter = 2.5mm

Fig. 3.1. Optimized Tool Geometry

4. Simulation

For different type of analysis and CFD we used Ansys Workbench 17.0 and Fluent.

Model prepared in the Solidwork 14.0 cannot be directly opened in ANSYS. We have to be converted it into a compatible format like IGES or STEP/STP for further processing. Pro-E model of the tool and work-piece assembly is first converted into STEP/STP format and then imported to ANSYS

To, finalised design first we performed modal analysis. Objective of modal analysis is to find out the critical mode.

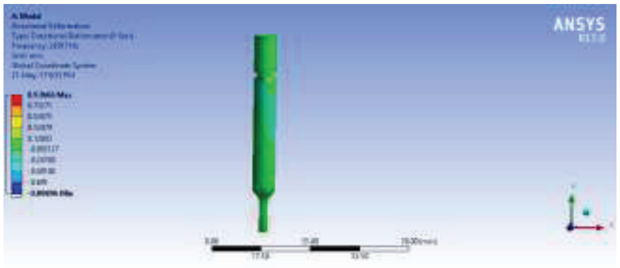

Fig. 4.1 Mode Shape

Deformation at different modes is under permissible limit for optimised design.

Once design is finalised, Harmonic Analysis is performed to calculate stress and displacement.

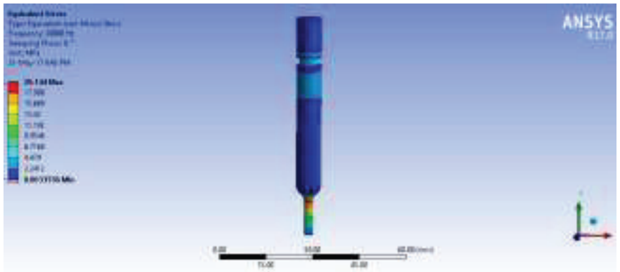

Fig. 4.2 Max Stress

After performing harmonic analysis maximum stress is calculated. Stress is 20 Mpa which is less than allowable limit.

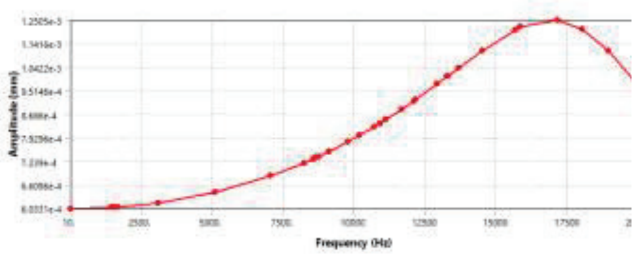

Fig. 4.3 Displacement vs. Frequency

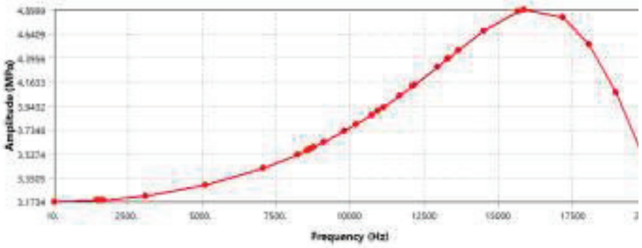

Fig 4.4 Stress vs. Frequency

From the above graph it is clear that displacement and stress is decreasing at working frequency.

Our Optimised design is safe for working frequency.

4.1 CFD Simulation

After importing the model from the Solidwork we assign the name for all the part to identify it by the name. Material points are created to indicate the fluid volume or solid volume. Different name of the parts are shown in the model tree. This fig.4.1.1 shows the different parts and their names.

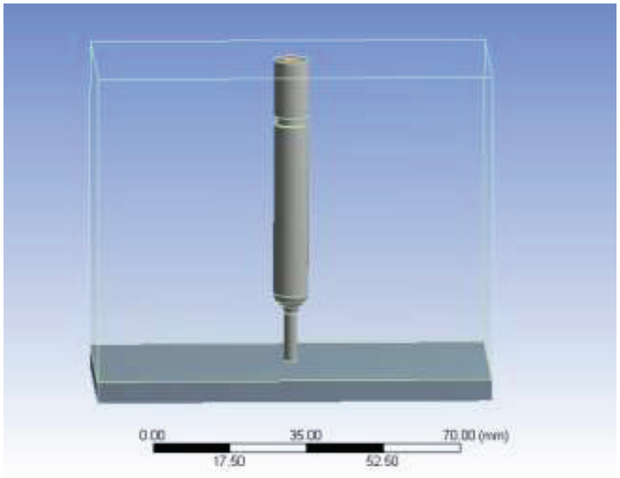

Fig. 4.1.1 Model for CFD Analysis

Meshing is used to discretizing a spatial domain in to simple geometric elements such as triangles (in 2D) or tetrahedral (in 3D) for getting the numerical solution. Meshes typically have to conform to boundaries. After importing the geometry and part naming we set the following parameters for meshing.

Workpiece- Hexa Elemet or Brick element is used with element size 5 mm.

Electorde- Tetrahedral element is used with minimum size of 0.5mm to conform all boundaries

Inflation in applied in inner volume of electrode with following parameter

Maximum layer 5

Growth Rate 1.2

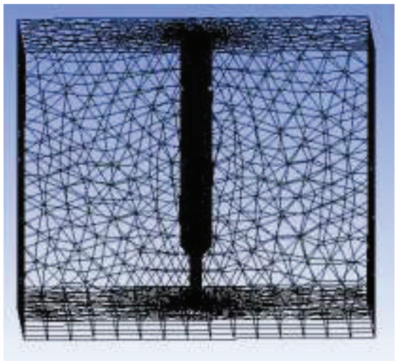

Fig. 4.1.2 Meshed box model with part naming\

No. Of Nodes	48839
No. Of Element	197951

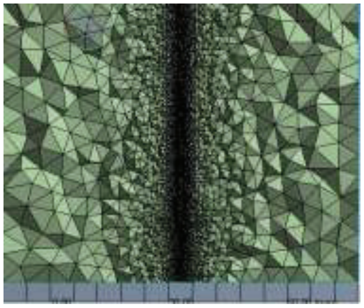

Fig. 4.1.3 Volume mesh at cut plane

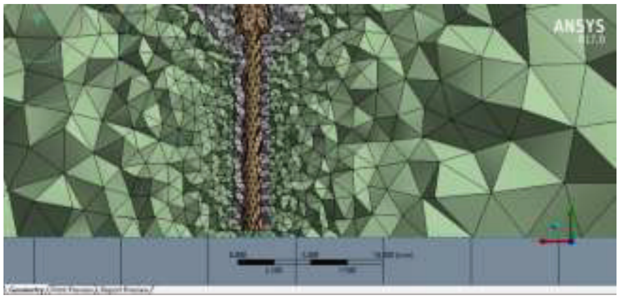

Fig. 4.1.4 Inflation at Wall Surface

5. RESULTS AND DISSCUSSIONS

This deals with the analysis of the results and discussion of the three models generated in ANSYS Fluent as per the mesh. It shows the crucial parameters affecting overall machining process of ECM in terms of contours from which we can predict the variation of these parameters in the IEG and their effects.

5.1. Velocity Profile

Figures 5.1, 5.2 and 5.3 show the velocity profile for model at inlet pressure 1.0kg/cm2, 1.2 kg/cm2 and 1.4 kg/cm2 respectively. The velocity profile at 1.0kg/cm2 pressure is as shown in Fig. 5.1 which indicates that velocity of electrolyte is increased from the hole to the boundary due to reduction in area of flow. The velocity of the electrolyte within the IEG will be 6.94m/s which is less than the outlet velocity. So as the fluid flow towards the work-piece the velocity will be decreases. There is a slightly change in velocity with In the IEG at different pressure.

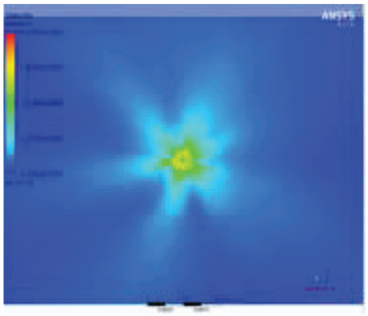

Fig.5.1 Velocity Profile at pressure 1.0 kg/cm2

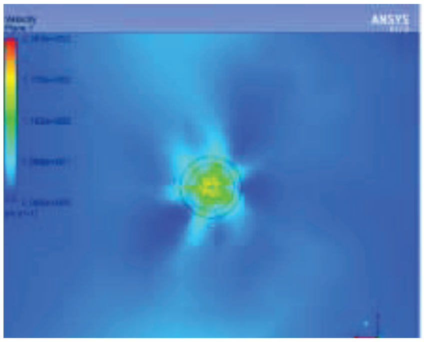

Fig.5.2Velocity Profile at pressure 1.2 kg/cm2

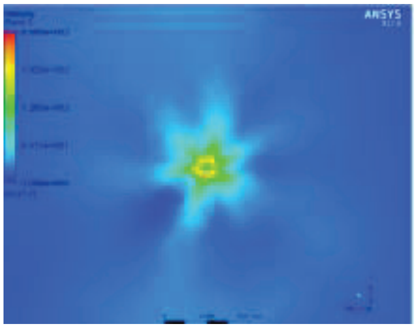

Fig.5.2Velocity Profile at pressure 1.2 kg/cm2

5.2 PRESSURE PROFILE

Figures 5.4, 5.5 and 5.6 describes the pressure contours for model with different inlet pressure 1.0 kg/cm2, 1.2 kg/cm2 and 1.4 kg/cm2 respectively in the inter electrode gap on the plane of work-piece

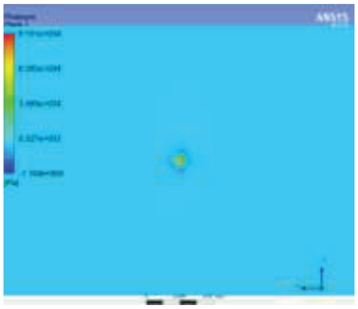

Fig.5.4. Pressure profile at inlet pressure 1.0 kg/cm2

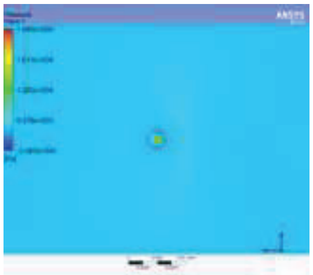

Fig.5.5. Pressure profile at inlet pressure 1.2 kg/cm2

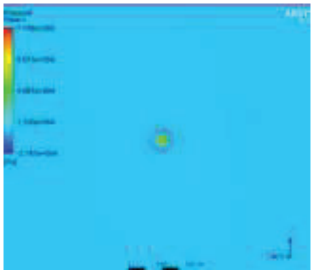

Fig.5.6. Pressure profile at inlet pressure 1.4 kg/cm2

The above pressure profiles describe about the variation in pressure in the IEG on the plane of machining area. As all the case shows that pressure will be higher at the center of the hole which is going to be decreases towards the boundary. The pressure increases from the inlet to outlet. The pressure within the IEG will be higher as compare to inlet pressure.

5.3 Flow pattern

Figs. 5.7, 5.8 and 5.9 show the streamline flow pattern for model with different pressure.

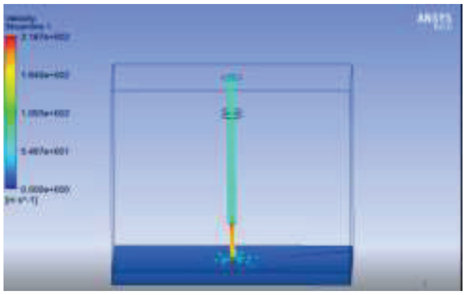

Fig.5.7Streamline flowpattern at pressure 1.0kg/cm2

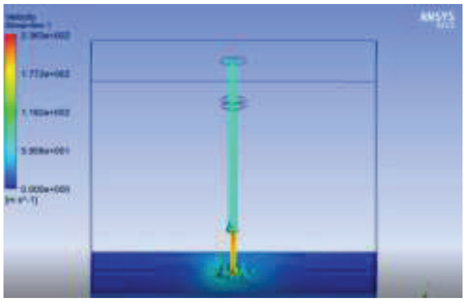

Fig.5.8Streamline flowpattern at pressure 1.2 kg/cm2

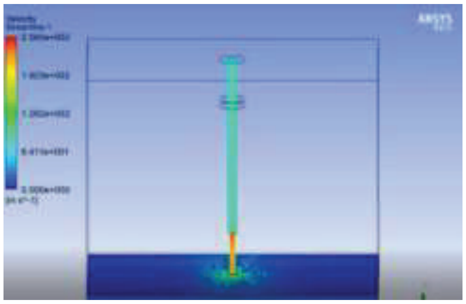

Fig.5.9Streamline flowpattern at pressure 1.4 kg/cm2

5.4 Turbulent Kinetic Energy Profile

Figs. 5.10, 5.11 and 5.12 show the turbulent kinetic energy contour within the IEG for model with different pressure.

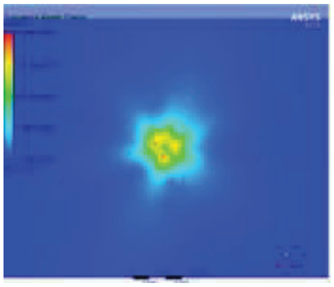

Fig.5.10 Turbulence kinetic energy profile at pressure 1.0kg/cm2

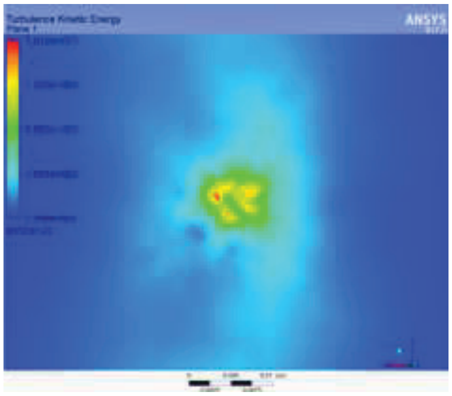

Fig.5.11 Turbulence kinetic energy profile at pressure 1.2kg/cm2

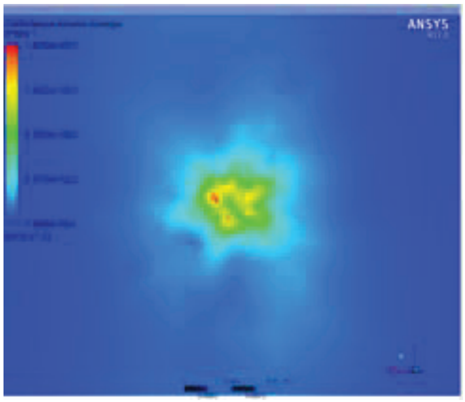

Fig.5.12 Turbulence kinetic energy profile at pressure 1.2kg/cm2

Turbulence in the k- ε model is depends on turbulent kinetic energy (k) and turbulent eddy dissipation rate (ε). Turbulence term is directly related to the surface roughness, If the turbulence within the IEG is more, then it means that roughness of the machined surface will be more. Turbulent kinetic energy determines the energy in the turbulence. Turbulent kinetic energy produced by fluid shear, friction or buoyancy or through external forcing at low frequency eddy scale.

5.5 Turbulent Eddy Dissipation Profile

Turbulent eddy dissipation gives the quantitative measurement of the turbulence. Figs. 5.13, 5.14and 5.15 represent the profiles of turbulent eddy dissipation for model within the pressure range 1.0 kg/cm2 to1.4 kg/cm2.

Fig.5.13 Turbulent eddy dissipation at pressure 1.0 kg/cm2

Fig.5.14 Turbulent eddy dissipation at pressure 1.2 kg/cm2

Fig.5.15 Turbulent eddy dissipation at pressure 1.0

This figures shows that the value of turbulent eddy dissipation is almost constant. It is very less within the IEG. The turbulence is also depends upon the eddy dissipation rate. If eddy dissipation rate will be high it will create more turbulence which affects the surface roughness

6. CONCLUSION

Three dimensional two phase flow pattern analysis of electrochemical machining with circular (hollow) tool provides fundamental idea of velocity distribution, pressure pattern, turbulence etc. in the IEG. A cubical SS work-piece, circular Copper tool and 15% sodium nitrate solution as electrolyte was considered in this analysis. Tool was modelled using Solidwork and analyzed in ANSYS FLUENT 17.0. To get consistent and good results, model was meshed with Fine mesh resolution. Model is analyzed with inlet pressure of 1.0 kg/cm2, 1.2 kg/cm2 and 1.4 kg/cm2respectively.

1) The flow velocity decreases when electrolyte moves towards the work-piece and it increases from inlet to outlet.

2) Turbulent kinetic energy and turbulent eddy dissipation rate profile exhibits higher value of turbulence at pressure 1.0 kg/cm2 and 1.4 kg/cm2 whereas at 1.2 kg/cm 2 pressure, turbulence is almost negligible.

3) The MRR is maximum affected by the tool feed rate and then voltage and lesser affected by the electrolyte pressure.

4) Hence, from the computational simulation and experimental results it was found that 1.2 kg/cm2 is a optimum value for pressure

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