In-Situ Mechanism of MRR and Circularity Predicted on SS 304 Steel by using ECM Process

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***Abstract*:- This paper is devoted to the study of enhancement of various ECM parameters like applied voltage and feed rate keeping other parameters constant on the surface roughness (Ra) using response surface methodology (RSM). By using RSM method in this report highlight on the features through which development of a comprehensive mathematical model for correlating interactive and higher- order influence of various machining parameters on the dominant machining criteria, the surface roughness. Optimal combination of these parameters is used in the order of achieve better optimisation of surface roughness, MRR and circularity which is in varying condition. The present work was an attempt to study the feasibility of SS304 tool in ECM. Based on the experimental result and analysis. The percentage contributions of most significant process parameters that is voltage towards the MRR and SR was found to be 36.71 and 25.05 respectively. This paper was focused on methods which are used to enhance metal removal rate (MRR) and surface finish during experimental investigations, were the work materials is SS304 also NaCl solution as electrolyte as a environment and moreover, increasing the MRR about (29.45%) and frequency from (100-500)HZ improved MRR by (34.17%).**

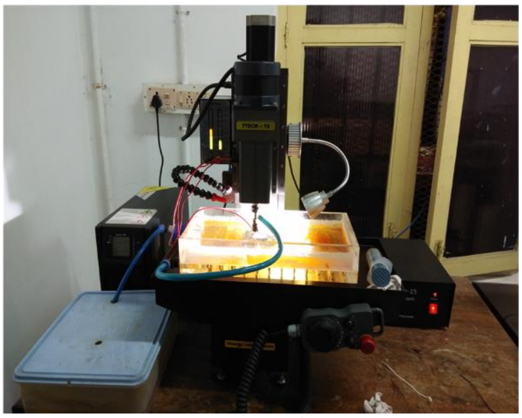
Keywords: ECM, Surface Roughness, MRR, Circularity, Taguchi method

INTRODUCTION:

Electrochemical machining or ECM is one of the most important conventional ma s for machining hard conducting materials which are difficult to shape, high strength and heat resistant materials into complex shape. ECM can cut small or odd shaped angles, intricate contours cavities in hard exotic materials, such as Titanium aluminides and nickel, cobalt, and rehenium alloys. Both external geometries and internal geometries can be machined. Here, the work piece is eroded accordance with Faraday's loss of electrolysis. The electric current passed through an electrolyte between a cathode and an anode. In which the cathode is tool and anode is workpiece

Electrochemical machining (ECM) is a machining process in which electrochemical machining process is used to remove material from workpiece. In this process, work piece is taken as anode and tool is taken as cathode. The two electrodes work piece and tool is immersed in an electrolyte (such as NaBr and NaCl) and the voltage is applied across the two electrode, the material remove from the workpiece starts. The workpiece and the tool is placed very close to each other without touching. In ECM the material removal take place at atomic level so it produces a mirror finish surface

- Complex and concave curvature parts can be produced easily by the use of convex and concave tools.
- Residual stresses are produced and no forces are present, because there is no direct contact between tool and workpiece.
- This process is used to machine only conductive materials.



Picture of ECM

Electrochemical machining (ECM) is a non-traditional process used mainly to cut hard or difficult to cut metals, where the application of a more traditional process is not convenient. Those difficult to cut metals demand high energy to form chips, which can result in thermal effects due to the high temperatures inherent to the process in the chip–tool interface. In traditional processes, the heat generated during the cut is dissipated to the tool, chip, workpiece and environment, affecting the surface integrity of the workpiece, mainly for those hard materials. Different from the other machining processes, in ECM there is no contact between
tool and workpiece. Electrochemical (electrolyses) reactions are responsible for the chip removal mechanism. The difficulties to cut super alloys and other hard-to-machine materials by conventional process have been largely responsible for the development of the ECM process

- It is always used for production of components of complex geometry and difficultto machine materials, e.g., turbine blades, blade disks, engine

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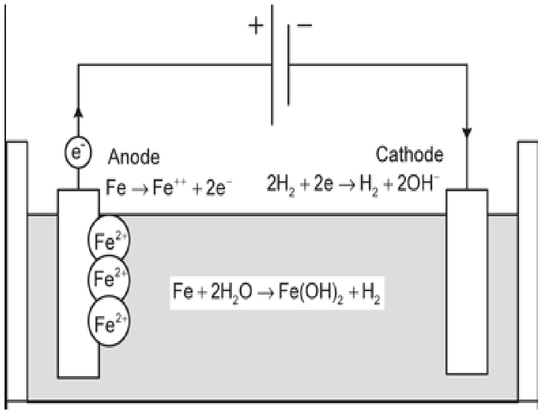
castings, gun barrel rifles,forge dies and molds, non circular holes

- Gusseff first patented electrochemical machining (ECM) in 1929
- Many years later in 1941, Burgess appeared with a publication in the Electrochemical Society. In the autumn of 1959, Anocut Engineering Company established the anodic metal machining technique as a commercially suitable technique. SIFCO (Steel improvement and Forge Company) followed with a commercial application one year later. The technique was applied in several ways as a machining technique in the 60's and 70's. In particular the gas turbine industry used the technique frequently
- The accuracy of machining can be improved by the use of pulsed electrical current. Controlling the wave pattern of pulsed current and the time of pulsed on/off is effective
- In this study SS304 workipece is used to study the effect of electrolyte flow rate on MRR and surface roughness , and the influence of voltage and frequency of pulsed power supply on MRR.



Reaction in ECM process

For an example of machining low carbon steel which is mainly composed of ferrous alloys (Fe). We use neutral salt solution of sodium chloride (NaCl) as the electrolyte to machine ferrous alloys. The ionic dissociation of NaCl and water take place in the electrolyte as shown below.

$NaCl \rightarrow Na^+ + Cl^-$

$H_2O \rightarrow H^+ + OH^-$

When the potential difference is applied across the electrode, the movement of ions starts in between the tool and the work piece. The positive ions moves towards the tool (cathode) and negative ions moves towards the work piece.

$2H^+ + 2e^- \rightarrow H2$

Apparently, the ion atoms comes out from the anode as Fe ions. Within the electrolyte, the sodium ions combines with Hydroxyl ions and form sodium hydroxide and ferrous ion combine with chloride ions and forms ferrous chloride. Also iron ions combine with hydroxyl ions and forms iron hydroxide.

$Na^+ + OH^- \rightarrow NaOH$

$Fe^{2+} + 2Cl^- \rightarrow FeCl2$

Where the electrolyte the $FeCl_2$ and $Fe(OH)_2$ produce and gets precipitated in the form of sludge and settle down in this way material is removed from the work piece as sludge. Tool feed system advances the tool towards the work piece and always keeps a required gap in between them the material from the work piece is comes out as positive ions and combine with the ions present in the electrolyte and precipitates as sludge. The sludge from the tank is taken out and separated from the electrolyte. The electrolyte after filtration again transported to the tank for the ECM process.

Taylsurf profilometer

Picture of Talysurf profilometer

This systems has low sound axes and high resolutio guage gives measurement integrity.The talysurf is easy to use and it is high accuracy instrument capable of roughness and waviness measurement. Decades of experience, ultra precision machining and FEA optimized design combine to provide low sound and near flow less mechanical executions of the measuring axes. Development of the use of traceble standards and exclusive algorithms usefully removes instrument influenece from the final results.

Video measurement system

Picture of Video Measurement System

Video technology is also used for inspection. The same benefits of magnifying a part to better resolve detail apply to devices used for visual inspection .such use isn't metrology, because the user subjectively analyzes the image, and nothing is measured .this use is more qualitative than quantitative. There is no universal definition of video inspection and some people refer to video inspection when they mean video measurement.

Estimation of experimental material removal rate (MRRexp):
The actual material removal rate can be determined by the
MRR= $(Wi - Wf) \div Txp$
Where, Wi = Initial weight before machining
Wf = Final weight after machining
T= Machining time

EXPERIMENTAL WORK:

Experimental work was involve the following experiments which were done by electrochemical cell consist of electrolyte solution (NaCl + water) and power supply DC current , and pulses power supply with pump for electrolyte flow rate and flow meter to register the electrolyte flow rate.
1- First experiments was done under the cutting conditions using different values of electrolyte flow rate and then calculate Metal Removal Rate (MRR) and surface roughness of work material by using surface roughness tester device.
2- Second experiments was done at different voltage to study the influence of machining voltage on MRR.
3- Third experiments was done at different frequency of pulses power supply to study the effect of frequency on MRR.

Power supply: The power supply is a very important device to provide the current that help the electrochemical reaction to occur by forcing the electrons to move from the workpiece through it to the tool. The power supply used in the experiment is a D.C power supply with a variable current (5 A/10V – 400A/36V) . Also pulses power supply is used with ECM cell 2 (0-32 VDC- 0-15 A).The positive pole is connected to the workpiece, while the negative pole to the tool.

Tool feeding device and controller: Provide the required feeding by using the controller which control the vertical movement of the machining tool with adjustable feeding speed, were two electrical motors are used to control the vertical movement of tool ,one motor used for feeding the tool dawn and the other for rising the tool up.

Electrolyte pump: Pump the electrolyte from the storage tank towards reaction chamber.

Electrolyte filtration: The filter is used to remove the sludge from the electrolyte. It is put inside the pump to clean the electrolyte before pumping.

Flow meter: Control the flow of electrolyte from storage tank towards reaction chamber.

Electrolyte tank:
Store the electrolyte for recycling to the reaction chamber.

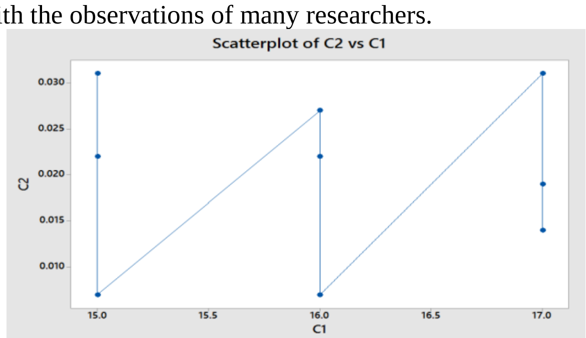
Reaction chamber:
The machining operation occur in this part of ECM cell, were required chemical reaction happen.

Gap indicator:
The gap indicator used to determine the gap before and through machining of ECM operation.

Specification of Work piece
SS304 alloy is selected for experiment work piece, SS304 stainless steel used for conduct this experiment.
Grade 304 is the standard 18/8 stainless is the most versatile and is used widely used SS. It is available in a large range of products, forms and finishes than any other material. It has good forming and welding characteristics. The balanced structure of grade 304 it to be severely drawn with intermediate annealing which has made this grade dominant in the manufacture of drawn stainless part such as saucepans and sinks.
Grade 304L, the low carbon stainless steel, does not require post welding and so it is extensively used in large gauges. Grade 304H with its high carbon. It find its application at higher temperature. This structure also gives these grades excellent toughness even down in cryogenic temperature.

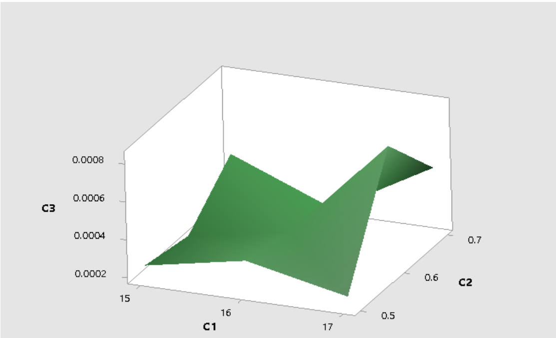
RESULTS AND DISCUSSION:

ECM machinability depends on the electrical conductivity of the electrolyte, feed rate of electrode, inter electrode gap and electrode flow rate the Influence of various machining parameters gap on MRR. The electrode feed rate has enormous effect on MRR and it increases with increases in feed rate. This Result was expected because the material removal rate increases with feed rate because the machining time decreases. MRR also increases with larger diameter of electrode; however, the effect is less than the feed rate on MRR. The electrode flow rate and conductivity has very little effect is less than the feed rate on MRR. The electrode flow rate and conductivity has very little effect on MRR and does not give any conclusive evidence of any impact on MRR and does not give any conclusive evidence of any impact on MRR. Similar trends shown by the plot of main effects for SN rotation on MRR the main effect of feed, diameter of the electrode, flow rate, conductivity are 1.1895, 0.2082, 0.0568 and 0.0538 respectively, on MRR in gm/min, in order of significance. These results are in good agreement with the observations of many researchers.



Graphical representation of Voltage (C1) VS Weight (C2)

Since, MRR effective is always more than MRR, for positive slug weight, show that with feed, both the MRR increases. The effect of electrode diameter on MRR effective is obvious as the projected area of electrode having fewer diameter is less than that of larger diameter electrode; the actual material removed under the projected area is less. Thus, with smaller electrode diameter, similar sized cavity can be made with lesser amount of material removed and saving energy. The influence of various machining parameters on MRR effective. The electrode feed rate has enormous effect on MRR effective and it increases with increases with larger diameter of electrode; however, the effective is less than the feed rate on MRR and does not give any conclusive evidence of any impact on MRR. Similar trends are shown by the plot of main effects for SN ratio on MRR .the main effects of feed, diameter of electrode, flow rate, conductivity are 9.749,1.100 and 0.537, respectively, on MRR effective in gm/min. in order of significance. There is very less difference between the graph of MRR and effective MRR.



Graphical representation of Voltage (C1) VS Feed rate (C2) VS MRR(C3)

Circularity inspection report

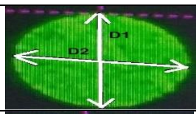
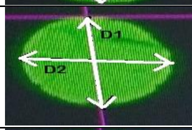
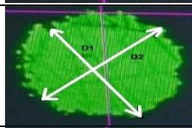
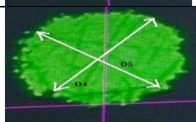
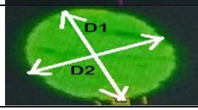
S.No	Specification	Electrolyte	D1 (mm)	D2 (mm)	Error (D1-D2) (mm)
1	DIA	NaCl	1.441	1.454	0.013
2	DIA	NaCl	1.275	1.253	0.022
3	DIA	NaCl	1.226	1.204	0.022
4	DIA	NaBr	1.310	1.326	0.016
5	DIA	NaBr	0.899	0.852	0.047
6	DIA	NaBr	1.145	1.100	0.045
7	DIA	$NaNO_3$	0.852	0.845	0.007
8	DIA	$NaNO_3$	1.186	1.197	0.011
9	DIA	$NaNO_3$	1.026	1.033	0.007

MRR investigation report

S NO	**VOLTAGE (amp)**	**Weight before (g)**	**Weight after (g)**	**Time (min)**	**MRR (cm^3/min)**
1	**15**	**7.40**	**7.37**	**15.33**	**2.5x10^{-4}**
2	**16**	**7.32**	**7.29**	**11.05**	**3.05x10^{-4}**
3	**17**	**7.29**	**7.26**	**8.29**	**5.14x10^{-4}**
4	**15**	**7.26**	**7.24**	**13.50**	**2.06x10^{-4}**
5	**16**	**7.24**	**7.22**	**12.38**	**2.22x10^{-4}**
6	**17**	**7.22**	**7.20**	**10.08**	**2.35x10^{-4}**
7	**15**	**7.20**	**7.19**	**20.04**	**4.37x10^{-4}**
8	**16**	**7.19**	**7.19**	**24.56**	**3.5x10^{-4}**
9	**17**	**7.19**	**7.17**	**21.09**	**8.3x10^{-4}**

The influence of various machining parameters on MRR effective. The electrode feed rate has enormous effect on MRR effective and it increases with increases with larger diameter of electrode; however, the effective is less than the feed rate on MRR and does not give any conclusive evidence of any impact on MRR.

Comparison of Circularity

S. No	**Voltage (amp)**	**Feed Rate (mm/min)**	**MRR (cm^3/min)**	**Circularity**
1	**15**	**0.5**	**2.5x10^{-4}**	
2	**16**	**0.6**	**3.05 x10^{-4}**	
3	**17**	**0.7**	**5.14 x10^{-4}**	
4	**15**	**0.5**	**2.06 x10^{-4}**	
5	**16**	**0.6**	**2.22 x10^{-4}**	
6	**17**	**0.7**	**2.35 x10^{-4}**	

In this following table found that the excellent circularity is obtained by the NaCl electrolyte at Voltage 15 (amp) and feed rate 0.5 mm/min and the least circularity is obtained by $NaNO_3$ electrolyte at Voltage 15 (amp) and federate is 0.5. and the circularity measured by video measurement system. In this experiment 3 electrolyte used from that NaBr is having voltage 17 and feed rate 0.7mm/min. The second NaCl electrolyte has a voltage of 16 and feed rate 0.6. The NaBr electrolyte has voltage 17 and feed rate 0.7. Here the second $NaNO_3$ has a voltage of 17 and the feed rate is 0.6.

CONCLUSIONS :

In this research , Experimental investigation lead to the following conclusions:

1- There is enhancement of surface finish when increasing electrolyte flow rate more than two time.

2- Voltage also has an a great effect on metal removal rate and surface roughness when increasing voltage of the metal removal rate will increase which reach to 30%.

3- High pulses number and high frequency causes enhancement of MRR more than 30%.

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