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PARAMETRIC OPTIMIZATION OF ELECTROCHEMICAL MACHINING ON SS316L

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Abstract — *The harder materials which are subjected to be machined using conventional methodology have their own drawbacks like lack in the accuracy, unpredictable wear of tool, introducing micro-cracks, surface distortions and produces internal stress in the work piece etc. To overcome these limitations of the conventional methodology, the non – conventional methods were elaborated. Undoubtedly these non-traditional processes are capable to machine and finish any type of complicated structures with the desired perfection, up to microns and furthermore to nanometer scale. Electro-Chemical Machining (ECM) process is an atomic finishing method. The conducted literature research reveals that ECM process is trending and have performed a number of applications in finishing of different type of products like aerospace engine parts, medical instruments, marine engine parts, watch casing, ,tools used in pharmaceutical industry . In present work done, an experimental setup of ECM process has been designed and developed to resolve the problems associated with the traditional machining. The finishing of cylindrical surface has been studied by using NaNo3 and the effect of input parameters viz. RPM, Voltage and Time, has been investigated. The response surface methodology was performed using Design Expert 11 (Box-Behnken Design) approach has been used for experimental design and analysis. The results of the experiments shows that the cylindrical SS316L is finished with chemical (NaNo3) and obtained maximum surface finish as 0.167 µm. The best results were found at 100RPM of work piece, Voltage 30V and time 2hrs. The PISF was improved by 64.03% over its original surface finish.*

Keywords*-Electro Chemical Machining; Performance Evaluation; Finishing; Machining Setup*

I. INTRODUCTION

Electro-chemical machining (ECM) is a methodology of removing metal by reverse electroplating procedure. It is unremarkably used for mass production and is employed for operating extraordinarily hard materials and materials that are tough to machine using typical machining process. Its use is restricted to electrically conductive materials. ECM can cut tiny or odd-shaped angles, cavities or complex contours in hard to machine and non-native metals, similar to Inconel, titanium aluminides and high nickel, cobalt, and rhenium alloys. All of these geometries can be machined internally and externally. ECM is usually designate as "reverse electroplating", in this it intends to remove material rather than plating layer or adding layer on it. It is similar in idea to electrical discharge machining (EDM) in this high current is induced between an electrode conductor of soft metal and the workpiece of hard metal, through an electrolytic material layer reaction removal method having a negatively charged tool (cathode), a semiconductive electrolytic fluid and a positively conductive piece of work (anode); but, in ECM there's no tool wear. The ECM electrode is lead on the specified direction over the work however without actually making contact with the material. In Contrast to EDM, no sparks are formed. The relative metal removal rates are highly attainable with ECM, without any kind of thermal or mechanical stress which is being transmitted to the workpiece from the machining process, and mirror like surface finish may be attained.

Conducting a literature survey it was found out that the Electrochemical Machining has remarkably improved the surface roughness results in various sectors however optimization still needs to be done for various materials. Ahn et al (2004), The ECM was used to investigate the micromachining as there are no limitations in case of electrical operations and studding the characteristics of ultra-short electrical pulse duration of 10ns was used to constrain the electrolyte medium. The manipulation of input variables were done on the workpiece of SS304 by considering different volts, pulse durations and different geometries. Zhang et al.[2], The micro machining process is hybridized to form the micro ultrasonic assisted lapping technique is used along with the Acoustic Emission monitoring system, which is a feedback system to provide input for the DNC system used to assist the automatic tool and workpiece contact detection and rate of wear. Diamond and alumina abrasives were used and it was concluded that the grit size affects the overall surface finish and the speed and not by the amplitude of vibration. Choi et al. [3], The chemical-assisted ultrasonic machining technique is adopted over the conventional laser or electrochemical discharge machining done on the surface of glass, it concluded that the surface roughness was refined and it also formed a smooth profile as compared to USM but there was an expansion of the hole diameter because of the chemical erosion of the profile Holstein et al. [4], for materials working under plasma facing conditions a high surface finish is required for longer stability under extreme working atmosphere and is such conditions material imperfections can lead to technical failures which are not tolerable. A pulsed supply is used to examine the various effects on micro cracks by conventional machining while using ECM and experiments revealed that the more the pulse frequency i.e.1000Hz the more was the surface finish and the micro cracks were minimum. Ghoshal et al. [5], The main focus is on the development of micro tool machining, for the fabrication of micro workpieces. In this tungsten tool is fabricated using the advanced pizeo electric actuator assisted electro chemical machining. A small SS ring is fabricated using vibration assisted tool with electrolyte flowing in the gap. It is concluded that reverse tapper is essential for drilling holes in to workpiece to overcome the problem of dia enlarging because of electro chemical process. Das et al. [6], ECM I widely used for machining of complicated structures with the bet surface finish so the optimization of this process is necessary. Optimization of the parameters are performed using taguchi L27 and Orthagonal array (OA) with parameters feed rate, electrolyte concentration , inter- electrode gap and the voltage. The experiments concluded that the optimum results were formed with electrolyte concentration of 10% NaCl and voltage 10V at a feed of 0.25 mm/min with inter-electrode gap of 0.2mm. Jeykrishnan et al. [7], ECM provides good surface finish but at the same time it is costly and its maintenance cost is quite high. So it`s essential to find out the perfect parameters of the machine tool. Also in ECM sometimes the material remove is so intense which is not required and thus a research has been conducted to optimize the process parameters of die steel and it was concluded that the main factor affecting the process termed out to be the current which is around 68% and all other factors were having the minimum impact. Sudiarso et al. [8], Optimization is the key to get work done without any error. Thus optimization of the electro chemical process is carried out on NaCl electrolyte and parameters like the voltage and the electrolytic concentration are considered. The results concluded that the concentration of the electrolyte i.e. NaCl at 200g/l was most effective at the voltage of 12.5 and the results represents higher MRR at this point. Whereas when the voltage and the concentration of NaCl was reduced the results dropped down to minimum. Guodong et al. [9], The process of micro level electro chemical machining of metallic alloys, the insoluble products in the electrolytic solution tends to resist the machining of micro hole`s with comparatively higher aspect ratios. The research was conducted to select the optimum electrolyte and to optimize composite electrolyte by investigating the disseverment and cleansing the electrolytic products evenly. The results for the optimum solutions were purposed for the Stainless Steel 304.Elanchezhian et al. [10], The optimization of ECM process is concluded by performing trials on D3 Die Steel to find out the optimum process parameters which influence the response. The obtained results were tabulated and analyzed using taguchi technique. The three main parameters considered for the amperes, electrolytic solution concentration and voltage to conclude the minimized surface roughness which is required for automotive industry. Xuezhen et al. [11], were used Titanium alloy (Ti60) for manufacturing of blades at optimized parameters of machining. In ECM process they took NaCl as electrolyte (13% as per weight) and 20 voltage for decreasing surface roughness. This work were performed with optimum parameters (such as power supply, feed of anode and pressure of electrolyte) which were created from L25 orthogonal method. Hence, the surface roughness has been developed 1.09 µm of blisk blades and also found that power supply is important factor which effect to surface roughness. Zhao et al. [12], The metal corroded in case of ECM operation dissolve in to the electrolytic solution which further contaminates the salt solution. For effective working of machine tool it is required to provide a suitable electrolyte treatment system to assist the reuse of the chemical solution and maintain the quality constant of the solution which is essential. The stirrer system and the activated carbon apparatus is used to control the ph of the solution and cleanse it from impurities. Koyano et al. [13], a new machine tool for ECM was developed. The porous structure of the tool allow the electrolyte to flow to be forced through its permeable structure. Which hence increases the machining efficiency without compromising the surface finish of the machined surface. This tool was developed using the laser sintering additive manufacturing technique and overall process time was quite low for hole drilling in the work piece with a porous free machined component. Also the machining speed can be increased with an increased electrolyte flow. Jey krishnan et al. [14] A study was conducted on silica glass for micro machining using a tungsten electrode on ECM machine considering the electrode feeding pressure and velocity with a rigid support and the time considered for finishing a cylindrical work piece was taken up to 1hr. It was concluded that the constant pressure of the feed was playing a dominate role over all other variable parameters.

II. PRINCIPLE OF ECM

In the ECM process, a tool (-ve charged) is advanced into a work piece (+ve charged). The controlled electrolytic solution is injected as a jet stream on a set temperature to the area being machined. The constant feed rate is provided because the rate of "liquefication" of the metal. The inter electrode gap and the piece of work varies within 80–800 micrometers. As electrons cross the gap, material from the piece of work gets dissolved, because the tool forms the required form in the workpiece. The electrolytic fluid also carries away the molten metal hydroxide residue in the electrochemical operation.

III. ECM SETUP

The experimental setup consists of a motorized chuck insulated with Teflon bush with variable RPM which are recoded using a diode rpm sensor, a horizontal one axis slide to facilitate the longitudinal machining and assisting the loading and unloading of the workpiece.

3.1. Working Principle of ECM Surface Finishing Machine

In ECM surface finishing machine, as shown in figure workpiece is given rotational moment and the copper electrode is placed on the top of the rotating job at a gap of 1-2mm. The electrolyte jet is allowed to flow form the one end of the tool which helps the flow to cover the circumferential gap of the tool and the workpiece surface. The used electrolyte is allowed to drain back to the sump and where a pump levitates the electrolyte to the working area as shown in fig.3.1 and 3.2.

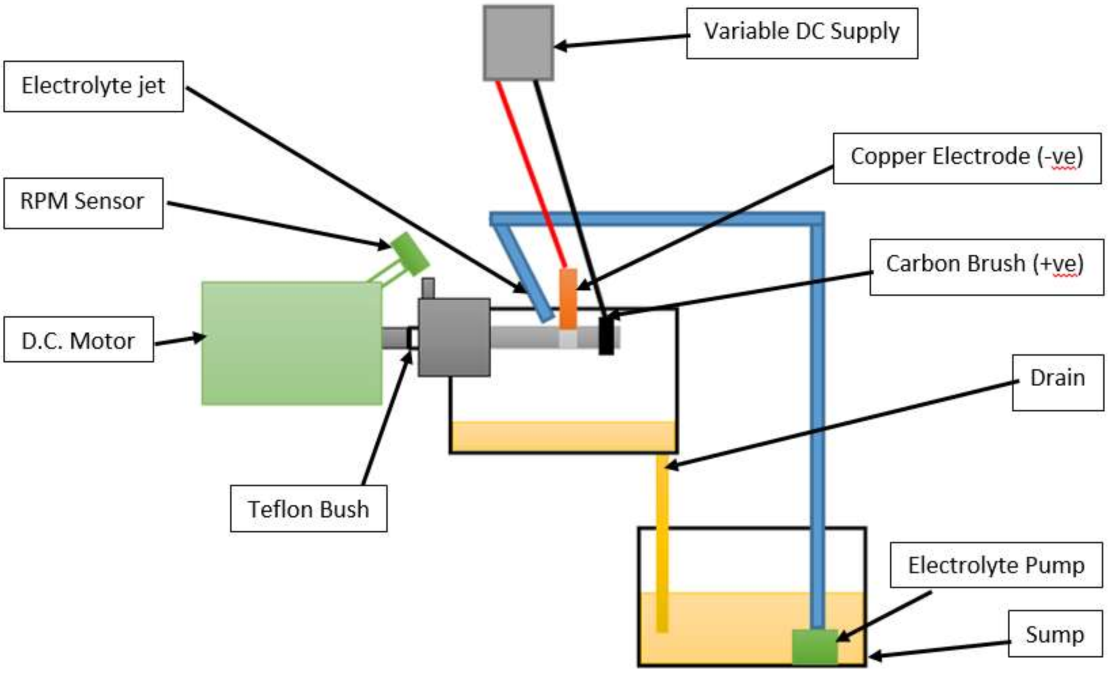

Fig.3.1 Front view of ECM surface finishing machine.

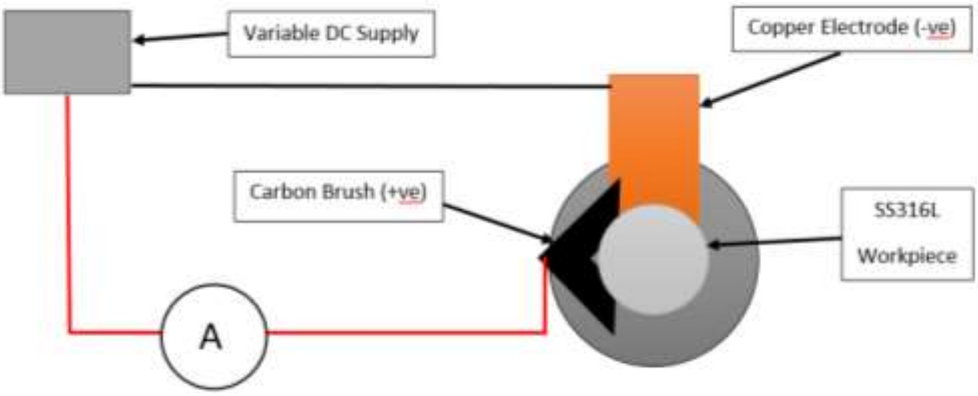

Fig.3.2 Side view of ECM surface finishing machine.

IV. EXPERIMENTATION

The experiment was performed on the prepared setup of ECM, and the electrolyte used was 12.5 % $NaNo_3$ on 1inch dia and 4-inch length rod specimens of SS316L. The variable parameters considered for the optimization of finishing SS316L are as following.

Table 4.1 Considered input parameters.

Parameter	Units	Type	Min.	Max.
Revolutions	Rpm	Factor	50	150
Voltage	V	Factor	20	30
Time	Hours	Factor	1	2

Table 4.2 Unconsidered parameters.

Parameter	Value
Electrolyte % ($NaNO_3$)	12.5%
Electrolyte flow	Constant
Ampere	3.5-3.6 amp

A copper electrode with a curvature at the end of dia respective to the work piece was used to perform the atomic layer removal from the work piece. The experiments were designed using Design Expert 11 (Box- Behnken design). A set of 17 designed experiments were recommended to obtain the optimum response for the given input factors.

Table 4.3 Experimental Data.

S. No.	RPM	VOLTAGE(volt)	TIME(hr)	PISF(%)
1	100	25	1.5	53.28
2	150	25	2	51.65
3	100	25	1.5	53.28
4	50	25	2	50.56
5	100	25	1.5	53.28
6	150	25	1	46.24
7	100	30	1	59.42
8	150	30	1.5	58.45
9	50	25	1	43.1
10	100	20	2	50.78
11	100	25	1.5	53.28
12	100	20	1	44
13	100	25	1.5	53.28
14	50	30	1.5	57.81
15	50	20	1.5	44.57
16	100	30	2	64.03
17	150	20	1.5	44.67

The surface roughness was tested using Mitutoyo Sj-410 which has a least count of about 0.001 µm and the cut length = 0.8mm. The surface roughness of the raw material or work piece taken before for finishing 0.456 µm and the results after the ECM finishing 0.167 µm.

V. CONCLUSION

The conclusions were drawn from the surface finishing performed using ECM on SS316L using the copper electrode. The maximum improved PISF or the surface finish obtained is 64.03% from the raw work piece initial surface roughness. The optimum process parameters for this result were speed 100 rpm, voltage 30V and the time taken 2hr. The minimum value of R_a obtained was 0.167 µm. The RPM range 100 is optimum for all the variables because at this range the electrolyte gets enough time to machine the work piece and flush out the electrolyte from the working gap. The setup developed for the precise machining using ECM can be successfully used to obtain the surface finish of about 0.2 µm.

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