CHAPTER 2

LITERATURE SURVEY

2.1 REVIEW OF LITERATURE

ECMM is an important machining process in many manufacturing industries, viz. aerospace, bio-medical, electrical, and electronics, automobile, thermal power plants, nuclear power plants, etc., where hard to cut materials are used. Several researchers have attempted to improve the performance characteristics of ECMM process by studying the effect of process parameters on the machining process. But the full potential utilization of ECMM process is yet to be achieved. This is due to complex and stochastic nature and number of variables involved.

2.2 OVERVIEW ON ECMM

The literature survey made for this research work revealed that the researches conducted on ECMM are related to recent trends in ECMM and effects of process parameters on MRR. It is also inferred that more research involving number of process parameters are to be done in this area.

The research titled "Electrochemical machining: new possibilities for micromachining" highlights various design and development activities of an ECMM system set up (Bhattacharyya B. 2002). A successful attempt has been made to develop an ECMM setup for carrying out in-depth independent
research for achieving satisfactory control of ECM process parameters to meet the micromachining requirements. The developed ECMM setup mainly consists of various sub-components and systems, e.g., mechanical machining unit, micro tooling system, electrical power, and controlling system and controlled electrolyte flow system, etc. All these system components are integrated in such a way that the developed ECMM system setup will be capable of performing fundamental research in the area of ECMM fulfilling the requirements of micromachining objectives.

The recent developments and future trends of EMM were highlighted in the research titled “Advancement in electrochemical micro machining” (Bhattacharyya B 2004). It suggests that micro-ECM (ECMM) method can be effectively used for high precision machining operations such as removal of burrs, making patterns in foils, and 3D micro-machining. The research suggests that for utilizing ECMM in micro fabrication, improvement in micro tool design and development, monitoring and control of the inter electrode gap (IEG), control of material removal and accuracy, power supply, and elimination of micro-sparks generation in IEG, and selection of electrolyte is required.

The study titled “Process monitoring of electrochemical micromachining” shows the importance of inter-electrode gap in ECMM set up (De Silva A.K.M 1998). Electrochemical micro-machining utilizes very small inter electrode gaps in order to obtain the accuracies. The narrow gaps make the control of process much more complex than normal ECM. In order to formulate spark prevention and gap control strategies, this paper investigate the discharge mechanism in narrow electrolytic gap.
The paper titled “Electrochemical micro-machining : new possibilities for micro-manufacturing”, highlights the design and development of ECMM set up which includes various component like mechanical machining components, electrical system and an electrolyte flow system etc. (Bhattacharyya B 2001). A microprocessor controlled IEG controlling system has been developed for this setup. The set up has versatile system components such as controlled tool feed, controlled electrolyte flow, and pulse power supply. The developed ECMM set up opens many challenging possibilities for effective utilizations of the electrochemical material removal mechanism.

The paper titled “A review of electrochemical macro to micro-hole drilling processes”, discusses about the Electrochemical machining processes for drilling macro and micro holes with exceptionally smooth surface and reasonably acceptable taper in numerous industrial applications particularly in aerospace, electronic, computer and micro-mechanics industries (Mohan Sen 2005). Also this paper highlights about the hole-drilling processes like jet electrochemical drilling have found acceptance in producing large number of quality holes in difficult-to-machine materials. This paper highlights the recent developments, new trends, and the effect of key factors influencing the quality of the holes produced by these processes.

The research titled “Selected problems of microelectrochemical machining”, included the study of electrochemical copying of slots, mini holes, grooves, and insulating groove features (Jerzy Kozac 2004). The limiting conditions of ECMM are considered from the point of view of copying and micro shaping using non profiled tool electrodes. For improving micro machining capabilities of ECM processes, the application of ultra short pulse current and ultra small gap size is recommended which is main point of discussion in this paper.
A rare application of electrochemical micromachining was discussed in the paper titled “Electro-chemical micro drilling using ultra short pulses” (Se Hyun Ahn 2004). In this work, ultra short pulses with tens of nanoseconds duration are used to localize dissolution area. The effect of voltage, pulse duration, and pulse frequency on localization distance were studied. High quality micro holes with 8 micron diameter were drilled on 304 stainless steel foil having 20 micron thickness.

An ECµM system with a machining gap control system was discussed in the research titled “A study of three-dimensional shape machining with an ECµM System” (Kurita T 2006). The applications of ultra short pulse current and ultra small gap size improves micromachining capabilities of ECM process. The utilization of edge cut electrode is advantageous to machine micro holes with high aspect ratio.

In the work titled “Localized electrochemical Micromachining with gap control”, an approach to electrochemical micromachining was presented in which side-insulated electrode, micro gap control between the cathode and anode, and the pulsed current are synthetically utilized (Li Yong 2003). An experimental set-up for electrochemical micromachining is constructed, which has machining process detection and gap control functions; also a pulsed power supply and a control computer are involved in. Microelectrodes are manufactured by micro electro-discharge machining (EDM) and side-insulated by chemical vapor deposition (CVD). A micro gap control strategy is proposed based on the fundamental experimental behavior of electrochemical machining current with the gap variance. Machining experiments on micro hole drilling, scanning machining layer-by-layer, and micro electrochemical deposition are carried out. Preliminary experimental results show the
feasibility of electrochemical micromachining and its potential capability for better machining accuracy and smaller machining size.

An experimental set up for micro electro chemical machining was developed with a machining gap control system for the research titled “Theoretical and Experimental investigation on electrochemical micro machining” (Zhang Z 2007). Experiments were conducted to identify the optimum parameters for machining voltage, pulse on time, piezo oscillation amplitude and electrolyte concentration. Based on the optimum parameters, three dimensional shapes with sub millimeter range was successfully machined.

The research titled “Electrochemical Micromachining of Stainless Steel by Ultra short Voltage Pulses” discusses the application of ultra short voltage pulses to a tiny tool electrode under suitable electrochemical conditions enables precise three-dimensional machining of stainless steel (Laurent Cagnon 2003). In order to reach sub micrometer precision and high processing speed, the formation of a passive layer on the work piece surface during the machining process has to be prevented by proper choice of the electrolyte. Mixtures of concentrated hydrofluoric and hydrochloric acid are well suited in this respect and allow the automated machining of complicated three-dimensional microelements. The dependence of the machining precision on pulse duration and pulse amplitude was investigated in detail.

A comprehensive mathematical model for analyzing the effects of various process parameters on the micro-spark and stray current affected zone was studied in the research titled “Control of micro spark and stray current effect during EMM process” (Munda J. 2007). Micro-spark and stray current
affected zone has been reduced as low as 0.0001 mm under proper controlled machining parametric combination.

The paper titled “Influence of tool vibration on machining performance in electrochemical micro-machining of copper” highlights the influence of various electrochemical micromachining parameters like machining voltage, electrolyte concentration, pulse period and frequency on material removal rate, accuracy and surface finish in microscopic domain (Bhattacharyya B 2007). According to their experimental study, the most effective values for micromachining parameters have been considered as 3 V machining voltage, 55 Hz frequency, and 20 g/l electrolyte concentration that can enhance the accuracy with highest possible amount of material removal.

The research titled “Experimental investigation on the influence of electrochemical machining parameters on machining rate and accuracy in micromachining domain”, has made an attempt to develop an EMM experimental set-up for carrying out in-depth research for achieving a satisfactory control of the ECMM process parameters to meet the micromachining requirements (Bhattacharyya B 2003). Keeping in view these requirements, sets of experiments have been conducted to investigate the influence of some of the predominant electrochemical process parameters such as machining voltage, electrolyte concentration, pulse on time, and frequency of pulsed power supply on the material removal rate (MRR) and accuracy to achieve the effective utilization of electrochemical machining system for micromachining. A machining voltage range of 6 to 10 V gives an appreciable amount of MRR at moderate accuracy
The paper titled “Experimental research on the localized electrochemical micro-machining” proposes a method of electrochemical micromachining of micro hole or dimple array, in which a patterned insulation plate coated with metal film as cathode is closely attached to work piece plate (Zhang Z 2008). When voltage is applied across the work piece and cathode film over which the electrolyte flows at high speed, hole or dimple array will be produced. The proposed technology offers unique advantages such as short lead time and low cost. The effect of process parameters on the microstructure shape was demonstrated numerically and experimentally. Arrays of holes or dimples of several hundred micrometers diameter have been produced.

The work titled “Experimental investigation into electrochemical micromachining (EMM) process”, with a suitable ECMM setup mainly consists of mechanical machining unit, micro-tooling system, electrical power, and controlling system and controlled electrolyte flow system to control electrochemical machining (ECM) (Bhattacharyya B 2003). Investigation indicates most effective zone of predominant process parameters such as machining voltage and electrolyte concentration, which give the appreciable amount of material removal rate (MRR) with less overcut. The experimental results and analysis on ECMM will open up more application possibilities for ECMM.

The research work titled “Experimental study on the influence of tool electrode tip shape on Electrochemical Micromachining of 304 stainless steel”, used an experimental set-up with constant gap control system (Thanigaivelan R 2010). The experimental study on the influence of tool tip shape on machining rate and machining gap for 304 stainless steel has been presented. The tool electrode tips of different shapes like flat ended, conical ended, round ended and wedge shape are used for this study. The experimental
results show that the round ended tip improves the machining rate and conical shape tip reduces the machining gap when compared with the other shapes.

In the paper titled “Experimental study of overcut in electrochemical micromachining of 304 stainless steel” an attempt was made to determine optimum machining condition of ECMM for 304 SS (Thanigaivelan R 2010). From the experimental results, it is evident that the most effective range of pulse on-time and electrolyte concentration can be considered as 25-30 ms and 0.23-0.29 mole/l, which gives lower overcut. Overcut increases with increase in pulse on-time and machining voltage. After the preliminary ECMM experiments the Taguchi experimental design has been applied to determine the optimal combinations of the machining parameters levels. According to the Taguchi’s quality design concepts, a L$_{16}$ orthogonal array was used. The optimal combinations of machining parameters levels for lesser overcut are machining voltage at 12V, pulse on-time at 25ms, machining current at 0.8 A and then electrolyte concentration of 0.29 mole/l.

An experimental study titled “Study of dominant variables in Electrochemical Micromachining” was carried out to determine the effects of dominant variables like pulse on time, electrolyte concentration and voltage on machining speed and overcut of stainless steel (Thanigaivelan R 2010). With the experimental results, it is inferred that machining speed reaches maximum at a pulse on time of 30 ms. The most effective range of pulse on time and electrolyte concentration can be considered as 25-30 ms and 0.23-0.29 mol/l which gives moderate machining speed and lower overcut.
The paper titled “Investigation into the influence of Electrochemical Micromachining (EMM) parameters on Radial Overcut through RSM-based approach” highlights the features of the development of mathematical model for correlating the interactive and higher-order influences of various machining parameters (Munda J 2010). This paper also highlights mathematical models for analyzing the effects of various process parameters on the machining rate and overcut phenomena. These parameters can be used in order to achieve maximization of the metal removal rate and the minimum overcut effects for optimal accuracy of shape features.

The work titled “Hole quality and inter electrode gap dynamics during pulse current electrochemical deep hole drilling” presents an experimental investigation of pulse-current shaped-tube electrochemical deep hole drilling (PC-STED) of nickel-based superalloy (Dayanand S. B. 2007). Influence of five process variables (voltage, tool feed rate, pulse on-time, duty cycle, and bare tip length of tool) on the responses, namely, depth-averaged radial overcut (DAROC), mass metal removal rate (MRRg), and linear metal removal rate (MRRl) have been discussed. Mathematical models have been developed to express the effects of these process variables. The proposed model permits quantitative evaluation of the hole quality and process performance simultaneously. The results have been confirmed for the profile of the drilled hole and MRRl obtained experimentally. In all the experiments, through holes of 26 mm depth with diameters ranging from 2.205 mm to 3.279 mm were drilled. The results have been explained by the inter electrode gap dynamics prevailing during pulse electrochemical deep hole drilling. Optimum parameters determined from these experiments can be used to efficiently drill high-quality deep holes.
The paper titled “Effect of over voltage on Material Removal Rate during Electrochemical machining” gives a report about the MRR in electrochemical machining by using over voltage and conductivity of the electrolyte solution (Mukherjee S.K 2005). It is observed that over voltage plays an important role equilibrium gap and tool feed rate. MRR decreases due to increase in over voltage and decrease in current efficiency, which is directly related to the conductivity of the electrolyte solution.

The study titled “State of the art of micromachining” discusses about the miniaturization in manufacturing various types of industrial products (Masuzava T 2000). Micromachining is the foundation of the technology to realize such miniaturized products. In this paper, the author summarizes the basic concepts and applications of major methods of micromachining. The basic characteristics of each group of methods are discussed based on different machining phenomena. Promising methods are introduced in detail hinting at suitable areas of application. Finally, the present state of these technologies is shown with examples of experimental and practical applications.

The work titled “Experimental investigation of microholes in electrochemical machining using pulse current” investigates the influences of some of the predominant electrochemical process parameters such as pulse frequency, feed rate of tool, machining voltage, and electrolyte concentration on the machining accuracy of micro-holes (Zhiyong Li 2008). According to the investigation, the most effective zone of pulse on time and electrolyte concentration can be considered as 15-50 µs and 30-50 g/l, respectively, which can gives a desirable machining accuracy for micro-holes. A machining voltage range of 6-10 V can be commended to obtain high machining accuracy. From the micrographs of the machined micro-holes, it may be observed that a lower value of electrolyte concentration with moderate
machining voltage and moderate value of pulse on time will produce more accurate shape of micro-holes.

In the paper titled “Electrochemical micromachining with ultrashort voltage pulses – a versatile method with lithographical precision” discusses about the application of ultrashort voltage pulses electrochemical reactions (Kock M 2003). As an example, electrochemical machining parameters for the micromachining of Ni are derived from conventional electrochemical cyclic voltammetry. Depending on the average potentials of tool and workpiece, overall corrosion of the workpiece and the location of the counter reaction of workpiece dissolution can be controlled. The pulse duration provides a direct control for setting the machining accuracy. Machining precisions below 100 nm were achieved by the application of 500 ps voltage pulses.

The research paper titled “Investigation into electrochemical micromachining (EMM) through response surface methodology based approach”, attempts to establish a comprehensive mathematical model for correlating the interactive and higher-order influences of various machining parameters through response surface methodology (RSM) (Munda J 2008). Validity and correctness of the developed mathematical models have also been tested through analysis of variance. Optimal combination of these predominant micromachining process parameters is obtained from these mathematical models for higher machining rate with accuracy. Considering MRR and ROC simultaneously optimum values of predominant process parameters have been obtained as; pulse on/off ratio, 1.0, machining voltage, 3 V, electrolyte concentration, 15 g/l, voltage frequency of 42.118 Hz and tool vibration frequency as 300 Hz.
The research paper titled “Improving Machining Accuracy of the EMM Process through Multi-Physics Analysis” studies the parametric effects of the EMM process by both numerical simulation and experimental tests (Shuo Jen Lee 2007). The numerical simulation was performed using commercial software, FEMLAB, to establish a multi-physics model which consists of electrical field, convection, and diffusion phenomena to simulate the parametric effects of pulse rate, pulse duty, electrode gap and inflow velocity. From the simulated results, the relationship between parameters, and the distribution of metal removal could be established. Proper process variables were also chosen to conduct the EMM experiments. After the experiments, the profile of the processed rectangular slot was measured by a Keyence digital microscope. Comparing profile of the processed rectangular slot with the profile of the cathode, the machining accuracy of EMM process could be determined. It could also verify the goodness of the multi-physics model for predicting machining accuracy. From this study, the effects of parameters such as pulse rate, pulse duty, electrode gap, and inflow velocity are better understood. The simulation model could be employed as a predictive tool to provide optimal parameters for better machining accuracy and process stability of the EMM process.

The investigation titled “Electrochemical micromachining, polishing and surface structuring of metals: fundamental aspects and new developments” discusses about the application of Electrochemical micromachining (EMM) as a versatile process for machining and surface structuring of metallic materials for biomedical and micro systems (Landolt D 2003). From a fundamental point of view EMM presents many similarities with electrochemical machining (ECM) and electro polishing (EP) provided one takes into account the scale dependence of phenomena. In the present paper the role of mass transport, current distribution, and passive films for shape control and surface smoothing is discussed and illustrated with
examples. The usefulness of numerical simulation using simplified models is stressed. New developments in EMM of titanium are presented, including oxide film laser lithography permitting EMM on non-planar surfaces without photo resist and the fabrication of two-level and multi-level structures. Scale resolved electro chemical surface structuring of titanium leads to well-defined topographies on the micrometer and nanometer scales, which are of interest for biomedical applications.

The technical paper titled “Improvement of Electrochemical Microdrilling Accuracy Using Helical Tool” presents a microhelical tool as a novel solution in electrochemical microdrilling process to improve the machining accuracy and ability (Hai-Ping Tsuia 2008). Fluent CFD is adopted to analyze the flow field status in process. The inlet and outlet diameters of the microholes are 425 µm and 362 µm, respectively; the values are obtained using the conventional microsolid cylindrical tool. When the rotation speed of the helical tool is 20,000 rpm, and the pulse-off time is 90 µs, the inlet and outlet diameter significantly decline to 335 µm and 299 µm. The experimental results reveal that the accuracy of microhole shape can be significantly improved using the microhelical tool in a simple and low-cost way.

The study titled “A study of the characteristics for electrochemical micromachining with ultrashort voltage pulses” about the application of voltage pulses between a tool electrode and a workpiece in an electrochemical environment that allows the three-dimensional machining of conducting materials with micrometer precision (Lee E.S 2007). In this paper, tool electrodes (5 µm in diameter, 1 mm in length) are developed by EMM and microholes are manufactured using these tool electrodes. Microholes with a size of below 50 µm in diameter can be accurately achieved by using ultrashort voltage pulses (1–5 µs).
The article “A step towards the in-process monitoring for electrochemical microdrilling”, presents a step towards the in-process monitoring based on waveforms generated during electrochemical micromachining (Mithu M.A.H 2011). An attempt has been made to correlate between the waveforms generated during machining and experimental outcomes such as material removal rate, machining time, and the dimensions of the microholes fabricated on commercially available nickel plate with prefabricated tungsten microtools. An electrical function generator is used as a signal source and a digital storage oscilloscope is provided for observing the nature of electrical pulses used and recording the waveforms generated during machining. The waveforms are subgrouped depending on the parameters used and analyzed to correlate the waveform shape and the machining outcomes. The digital storage oscilloscope also facilitates for observing the short-circuit condition which may occur during microdrilling. These results show that the shape of the waveforms and their corresponding values are in good agreement with the material removal rate, machining time, and on the dimension of fabricated microholes. Therefore, the proposed monitoring technique can be employed as a predictive tool in electrochemical micromachining.

The research titled “Research on pulse electrochemical finishing using a moving cathode” discusses about the improvement of the surface quality of parts with a finishing method Pulse Electrochemical Finishing (PECF) using a Moving Cathode (Jinjin Zhou 2005). The results reveals that machining with an inter electrode gap as small as possible could smoothen the anode surface quickly; with an invariable gap size, the current density and the machining time are two key parameters influencing the smoothening effect; there is a critical current density above which a bright surface could be obtained, and this process could finish a large surface area over the critical current with a low power supply, which is helpful to get a lustrous surface.
The result shows that the surface roughness value (Ra) reduces from 0.5 to 0.065 µm and a mirror-like surface is obtained.

The research work titled “A material removal analysis of electrochemical machining using flat-end cathode” discusses about the process to erode a hole of hundreds of micrometers on the metal surface (Hocheng H 2003). The paper also discusses the influence of experimental variables including time of electrolysis, voltage, molar concentration of electrolyte and electrode gap upon the amount of material removal and diameter of machined hole. The results of experiments show the material removal increases with increasing electrical voltage, molar concentration of electrolyte.

The research article titled “Optimization of electro-chemical machining process parameters using genetic algorithms” discusses about the optimum choice of the process parameters for the economic, efficient, and effective utilization of these processes (Jain N.K 2007). Process parameters of AMPs are generally selected either based on the experience, and expertise of the operator or from the propriety machining handbooks. In most of the cases, selected parameters are conservative and far from the optimum. This hinders optimum utilization of the process capabilities. Selecting optimum values of process parameters without optimization requires elaborate experimentation which is costly, time consuming, and tedious. Process parameters optimization of AMPs is essential for exploiting their potentials and capabilities to the fullest extent economically. This paper describes optimization of process parameters of four mechanical type AMPs namely ultrasonic machining (USM), abrasive jet machining (AJM), water jet machining (WJM), and abrasive-water jet machining (AWJM) processes using genetic algorithms giving the details of formulation of optimization models, solution methodology used, and optimization results.
The study titled “Development of micro machining for air-lubricated hydrodynamic bearings” uses a specially-built EMM / PECM (Pulse Electrochemical Machining) cell, an electrode tool fitted with non-conducting material, a electrolyte flow control system and a small & stable gap control unit are developed to achieve accurate dimensions (Park J.W 2002). Two electrolytes, aqueous sodium nitrate and aqueous sodium chloride are investigated in this study. The former electrolyte with few pits on the surface of workpiece has better machine-ability than the latter one with many pits on the surface of workpiece. It is easier to control the machining depth precisely with pulse electrical current than direct electrical current. This paper also presents an identification method for the machining depth by in-process analysis of applied electrical current and inter electrode gap size. The inter electrode gap characteristics, including pulse electrical current, effective volumetric electrochemical equivalent and electrolyte conductivity variations, are analyzed using the model and experimental results.

The research work titled “Micro and nano machining by electrophysical and chemical processes” discusses the issues related to the supporting technologies such as standardization, metrology, and equipment design (Rajurkar K.P 2006). Non-technological issues including environmental effects and education are also discussed.

The investigation titled “Parametric optimization of electrochemical machining of Al/15% SiCp composites using NSGA-II” discusses about optimal parameters for improving cutting performance (Senthilkumar C 2011). MRR and surface roughness are the most important output parameters, which decide the cutting performance. There is no single optimal combination of cutting parameters, as their influences on the metal removal rate and the surface roughness are quite opposite. A multiple regression model was used to represent
relationship between input and output variables and a multi-objective optimization method based on a non-dominated sorting genetic algorithm-II (NSGA-II) was used to optimize ECM process. A non-dominated solution set was obtained.

Application of an environmentally friendly electrolyte of citric acid for micro electrochemical machining of stainless steel has been discussed in the research paper entitled “Micro fabrication by electrochemical process in citric acid electrolyte” (Shi Hyoung Ryu 2009). Micro holes of 60 µm in diameter with depth of 50 µm and 90 µm in diameter with the depth of 100 µm are perforated using citric acid electrolyte.

The experimental work titled “Intervening variables in electrochemical machining” throws light on intervening variables in electrochemical machining (ECM) of SAE-XEV-F Valve-Steel (Joao Cirilo da Silva Neto 2006). In this research, the material removal rate (MRR), roughness and over-cut were studied. Four parameters were changed during the experiments: feed rate, electrolyte, flow rate of the electrolyte and voltage. Forty-eight experiments were carried out in the equipment developed. Two electrolytic solutions were used: sodium chloride (NaCl) and sodium nitrate (NaNO₃). The results show that feed rate was the main parameter affecting the material removal rate. The electrochemical machining with nitride sodium presented the best results of surface roughness and over-cut.

The Micro electrochemical machining (ECM) using ultra short pulses with sulfuric acid as electrolyte to machine 3D micro structures on stainless steel was discussed in the paper titled “Micro Electrochemical Milling” (Kim B.H 2005). This paper shows how to prevent taper, by using a disk-type electrode. To
improve productivity, multiple electrodes were applied and multiple structures were machined simultaneously. Since the wear of electrode is negligible in ECM.

The article titled "Taguchi concepts and their applications in marine and offshore safety studies" discusses about how the Taguchi concepts such as ‘quality loss function’, ‘signal-to-noise ratio’, ‘orthogonal arrays’, ‘degree of freedom’ and ‘analysis of variance’ may be synthesized in maritime safety engineering studies (How Sing Sii 2001). Brainstorming, an integral part of the Taguchi philosophy, is also briefly discussed. Orthogonal arrays are used to study many parameters simultaneously with a minimum of time and resources to produce an overall picture for more detailed safety-based design and operational decision-making. The S/N ratio is employed to measure quality; in this case, risk level. The loss function is considered as an innovative means for determining the economic advantage of improving system safety or operational safety. Noise factors are considered as any uncontrollable or uncontrolled variables or any other undesired influences.

The article, “Optimizing feed force for turned parts through the Taguchi technique” discusses about an optimal setting of turning process parameters (cutting speed, feed rate and depth of cut) resulting in an optimal value of the feed force when machining EN24 steel with TiC-coated tungsten carbide inserts (Hari Singh 2006). The effects of the selected turning process parameters on feed force and the subsequent optimal settings of the parameters have been accomplished using Taguchi’s parameter design approach. The results indicate that the selected process parameters significantly affect the selected machining characteristics. The results are confirmed by further experiments.
The research paper titled “Micro fabrication by electrochemical metal removal” discusses about the recent advancements in the electrochemical metal removal processes for micro fabrication (Datta M 1998). After a brief description of the process, several important parameters are identified that determine the material-removal rate, shape control, surface finishing, and uniformity. The influence of surface film properties, mass transport, and current distribution on microfabrication performance are discussed. Several examples of microelectronic component fabrication are presented. These examples demonstrate the challenges and opportunities offered by electrochemical metal removal in microfabrication.

The research paper titled "Electrochemical micromachining: An environmentally friendly, high speed processing technology" discusses about the wet chemical etching processes that are employed in the manufacturing of a variety of microelectronic components (Datta M 1997). These processes use etchants that generally contain aggressive and toxic chemicals, generate hazardous waste and have limited resolution. Electrochemical metal removal is an evolving alternate processing technique that involves controlled metal shaping by an external current, thereby requiring less aggressive and nontoxic electrolytes. The application of controlled electrochemical metal removal in the fabrication of microstructures and micro components is referred to as electrochemical micromachining (EMM). In this paper a recently developed EMM process and tool for metal mask fabrication is discussed. EMM performance is compared to that obtained by the conventional chemical etching process. Obtained results demonstrate the opportunities offered by EMM particularly as a high-speed, environmentally friendly processing technology.

The investigation work titled "Ultrasonic measurement of the inter electrode gap in electrochemical machining" discusses about the dependency of
the inter electrode gap with time and process parameters and its usage to determine process characteristics (Clifton D 2002). Defining process variables to map out the required gap-time function requires the use of time-consuming iterative trials. In-line monitoring of the gap would enable process control and tool to workpiece transfer characteristics to be achieved (for ideal conditions) without the requirement to generate such parameter maps. This work explores the use of ultrasound applied as a passive, non-intrusive, in-line gap measurement system for ECM. The accuracy of this technique was confirmed through correspondence between the generated gap-time and current time data and theoretical models applicable to ideal conditions. The monitoring of the gap size has also been shown to be effective when determining shape convergence under ideal conditions, for the example case of a 2D sinusoidal profile.

2.3 OUTCOME OF LITERATURE REVIEW

The literature survey helped to successfully design, construct and conduct the experimentation of this research work. Some of the major ideas learnt from the literature survey are listed below.

1. The experimental setup is designed based on the various requirements stated by above cited literature.
2. The specific studies of each process parameters made by various authors on for MRR and Dimensional deviation are helpful to understand the behaviour of each parameter.
3. Necessary ideas were obtained for making a suitable tool for the current study.
4. Clear outline about Taguchi methodology, and various other optimization techniques were learnt.
5. It is learnt that experimental investigation considering 5 most
influencing process parameters viz. Electrolyte Concentration, Machining Voltage, Machining Current, Duty Cycle, and Frequency on MRR is yet to be conducted.

6. It is understood that further research is to be conducted on Nickel and its alloys for maximum MRR.

7. Further study is needed in the area of Dimensional deviation.

Hence, it is inferred that more in depth research involving maximum number of process parameters are to be conducted to achieve maximum MRR with less dimensional deviation for Nickel and its alloys.