CHAPTER 2

LITERATURE REVIEW

This chapter begins with an overview of the non-conventional machining problems attempted. The literature covers a wide range of non-conventional machining operations such as Electrical Discharge Machining (EDM), Wire Electrical Discharge Machining (WEDM) and optimization of machining parameters in nonconventional machining processes. It also features experimental analysis, Taguchi method, ANN and non-traditional algorithms and their implementation on various engineering applications.

2.1 INTRODUCTION

In non-conventional machining, considerable amount of material is removed from the raw material to get the desired profile. This fact leads metal removal, a more expensive process when compared to other manufacturing processes. So cost consciousness is very much expected in producing a component. There are no scientific and economics approaches to reduce the non-productive times but there are considerable possibilities in reducing the machining time without detracting the quality of the machined component. Nowadays, greater attention is given to Material Removal Rate (MRR), surface roughness and dimensional accuracy of the products by the industry. There is a need to select the machining parameters for satisfying the customer requirements. Due to high investment and machining cost of non-conventional machines, there is an efficient need to operate the machines as efficiently as possible to get the required payback. The cost of machining is sensitive to the selection of machining variables. The machining variables are selected properly by using optimization techniques.
2.2 NON TRADITIONAL MACHINING PROCESS – AN OVERVIEW

Alauddin et al (1995) developed the mathematical model of surface roughness for the end milling of 190 BHN steel considering only the centre line average (CLA) roughness parameter (Ra) in terms of cutting speed, feed rate and depth of cut using response surface method (RSM).

Ahmet Hasçalık et al (2008) investigated the effect and optimization of machining parameters on surface roughness and tool life in a turning operation by using the Taguchi method. The experimental studies were conducted under varying cutting speeds, feed rates and depths of cut. An orthogonal array, the signal-to-noise (S/N) ratio, and the analysis of variance (ANOVA) were employed to the study the performance characteristics in the turning of commercial Ti-6Al-4V alloy using CNMG 120408-883 insert cutting tools. The conclusions revealed that the feed rate and cutting speed were the most influential factors on the surface roughness and tool life, respectively. The surface roughness was chiefly related to the cutting speed, whereas the axial depth of cut had the greatest effect on tool life.

Ali Özgedik et al (2008) investigated the variations of geometrical tool wear characteristics like edge and front wear, machining performance outputs – namely, work piece removal rate, tool wear rate, relative wear and work piece surface roughness with varying machining parameters. Experiments were conducted using steel work pieces and round copper tools with a kerosene dielectric under different dielectric flushing conditions (injection, suction and static), discharge currents and pulse durations. The experiments have shown that machining parameters and dielectric flushing conditions had a large effect on geometric tool wear characteristics and machining performance outputs.
Akshay et al (2008) were machined MMC consisting of Al6063 with SiC by using EDM process. Al6063 is used in a variety of applications such as electrical components, heat sinks and architectural fields. Hence, in this work, it is planned to investigate the effect of WEDM process parameters such as pulse-on time (TON), pulse-off time (TOFF), gap voltage (V) and wire feed (F) on MMCs consisting of Al6063 with various volume fractions of SiC and to compare the results with that of unreinforced Al6063 considering MRR and Ra.

Assarzadeh and Ghoreish (2008) presented a neural-network based approach for the prediction and optimal selection of process parameters in die-sinking EDM. They developed a back propagation neural network model to measure the performance (MRR and Ra) to be predicted in terms of three control parameters such as current, pulse period, and source voltage. ANN has been used in many other fields of manufacturing also.

Asli Secilmis et al (2009) studied the Electrical Discharge Machining (EDM) parameters and also determine the best adhesion at the interface of machined titanium porcelain composite. Then multiple level experiments were conducted to determine how the effective parameters varied over a wide area. Slopes of the curves obtained in these tests were studied, and then, final tests were conducted to obtain the best bonding strength possible. In the experimental results, parameters that offer the maximum adhesion and minimum adhesion are relatively specified ranges.

Akm Asif Iqbal et al (2010) reported on the experimental investigation of MRR, EWR and surface roughness in EDM milling of Stainless Steel AISI 304. The authors established empirical relations regarding machining parameters and the responses in analyzing the machinability of the stainless steel. Response surface methodology was used to investigate the relationships and parametric interaction between the three
controllable variables on the MRR, EWR and surface roughness (Ra). The developed model showed that voltage and rotary motion of electrode are the most significant machining parameters influencing MRR, EWR and Ra.

Biing et al (1999) studied the effect of machining parameters of wire cut EDM on composite materials. The Open gap voltage and pulse-on time are identified as significant influencing parameters on material removal rate in wire-cut EDM of aluminum composites.

Benardos et al (2002) have presented a Neural Network model for the prediction of surface roughness.

Boujelbene et al (2009) studied the influence of machining parameters on the surface integrity on materials X200Cr15 and 50Crv4 steel by using electrical discharge machining. The methodology consists of the analysis and determination of the white layer thickness, MRR, EWR and the micro hardness of each pulse discharge energy and parameters of EDM. The results of the tests undertaken in this study show that increasing energy discharge increase instability and therefore, the quality of the work piece surface becomes rougher and the white layer thickness increases.

Cogun and Savsar (1990) investigated the random behaviour of the time-lag durations of discharge pulses using a statistical model for different pulse durations, pulse pause durations, and discharge currents in EDM. The material removal contributions of discharge pulses are expressed in terms of the machining parameters. The determination of machining settings for the minimum electrode wear ratio was found by using Taguchi parameter design method.

Chen et al (1996) have developed an algorithm based on the Simulated Annealing (SA) algorithm and Hooke-Jeeves Pattern Search (PS)
for multi-pass turning operations. Experimental results indicated that the proposed non-linear constrained optimization algorithm SA / PS was effective for solving complex machining problems.

Choudhri et al (2002) have also suggested Genetic Algorithm to find the optimum machining conditions in turning. In this work two objective functions namely unit production time and unit production cost were optimized after satisfying few practical constraints.

Dauw et al (1989) noticed that the wire electrical discharge machining accuracy depends on the mechanical interaction during the machining process. They proposed and used measurement and acquisition system to improve the cutting precision by the using of suitable detection and control algorithms.

Dan Scott et al (1999) used a factorial design method to determine the optimal combination of control parameters in WEDM, the measures of machining parameter being the metal removal rate and the surface finish.

Dodun et al (2009) focused on establishing a means for characterizing shape error. Moreover, the influence exerted by certain factors, such as the corner angle and the thickness of the work piece on the above-mentioned machining error was quantified.

Ermer (1997) reviewed most of the reported studies on machining optimization. This literature concentrated on the economical optimization studies of the metal removal processes which took place essentially in the twentieth century.

Eva Portillo et al (2009) presented the design and development of a real-time monitoring and diagnostic system for diagnosing the degraded
behaviour in wire-electro discharge machining. It has been applied to develop a real-time monitoring and diagnostic system that uses virtual sensors to diagnose the degradation of the process. The results of this work gave a satisfactory performance of the presented approach.

Gadalla et al (1989) studied the Surface topography of WEDM surfaces in WC-Co composite. It is revealed that the cutting rate increases with increasing Co content in the composite. Their investigations showed that cubic WC and W2C have been formed on the cut surface and in the debris. The debris also contained ternary phases of W-C-Co, oxidized products and alloys of Cu-Zn and Co-Mo.


Garg et al (2010) presented a review of EDM process and year wise research work done in EDM on MMCs and also discussed the future trend of research work in the same area.

Horacio et al (2011) used ANOVA and regression models were used to predict the EDM output performance characteristics, such as MRR, EWR and SR in the EDM process for AISI 1045 steel with respect to a set of EDM input parameters In addition, it is noted that this approach has only considered a limited number of parameters.

Indurkhya and Rajurkar (1992) developed a 9–9–2-size back-propagation neural network for orbital EDM modeling. Having compared the results of the neural network model with estimates obtained via multiple regression analysis, they concluded that the neural model is more accurate and also less sensitive to noise included in the experimental data. Although the
various effects of changes of input parameters on the process outputs were analyzed and interpreted through the network model, they did not present any way of determining optimal input conditions to optimize the process for an arbitrary desired surface roughness (Ra).

Jeswami (1979) reported in EDM of different materials, there are still few works on EDM fast hole drilling of aerospace alloys. The author attempted to drill small holes ranging from 0.19 – 0.71 mm diameter in High Carbon Steel using copper wire.

Jeswani (1981) investigated the effects of the addition of graphite powders to kerosene used as the dielectric fluid in EDM. He observed that the addition of graphite powder resulted in an increase in the interspace for electric discharge initiation and lowered the breakdown voltage. It was also found that the machining process stability was improved in terms of gaining greater material removal rate (MRR). Later, a number of workers started to conduct tests using different kinds of minute particles for EDM of high-strength, high-hardness materials, and even brittle ceramics.

Jia et al.(1997) reported that for machining of advanced ceramics, the combination of ultrasonic machining and EDM may provide a higher material removal rate (MRR).

Jayaraman et al (2000) have presented a new co-operative search approach, Ant Colony Optimization for the optimal design and scheduling of batch plants.

Juan et al (2003) have reported an abductive network to model the high speed milling operation. The process variables have been optimized using Simulated Annealing algorithm with minimization of production cost as the objective function.
Jean Ming-der et al (2004) presented the application of the Taguchi method to develop an optimised electron-beam surface hardening of cast iron for high wear resistance. The experiments were conducted on both the ductile and grey cast iron. The factors investigated during the surface-hardened process included the material matrix, the accelerating voltage, the electrical current, the travel velocity, the melted width, the beam oscillation, and the post-heat treatment temperature. In this study, the L18 and L9 orthogonal arrays were introduced through the two-stage experimental designs and trials. Smaller-is better was used as a quality characteristic to evaluate the experimental results by computing their signal-to-noise (S/N) ratios of the wear volume after wear tests.

Josko Valentincic et al (2007) achieved a high removal rate and low electrode wear in a sinking electrical discharge machining process (EDM), rough machining parameters had selected according to the size of the eroding surface. This work showed that the electric current signal in the gap depends on the size of the eroding surface. The significance of the process attributes of the electric current signal is established by inductive machine learning and the general decision rules are derived.

Josko Valentincic et al (2009) used inductive machine learning, the percentage of short circuit and arc discharges in EDM rough machining turned out to be the enough informative attributes for determining machining parameters for stable and effective roughing. The results of this research clearly show the way to a simple and effective system for online selection of the rough machining parameters in EDM. A model was built on the signals in the clean and contaminated gap, thus the selection of the roughing parameters should not be affected by the contamination of the gap.

Joshi et al (2010) carried out a number of analyses on the single spark operation of EDM with consideration to the two dimensional axis-
symmetric process continuums. This analysis has many realistic assumptions like Gaussian distribution of heat flux, spark radius equation based on discharged current and duration, latent heat of melting etc, in order to predict the crater cavity shape and the Metal Removal Rate (MRR). A model is developed and machining parameters are studied.

Kinoshita et al (1982) proposed to stop power supply temporarily as soon as the pulse frequency dramatically increased. By this control strategy, preventing wire from rupture can be achieved but the process stability and the quality of the product cannot be assured.

Kremer et al (1991) reported that the EDM process is strongly influenced by the hydrostatic pressure, which governs the hydrodynamic pressure changes during the discharge. Also they have shown that the synchronization of discharges with ultrasonic vibration in ultrasonically assisted EDM increases the material removal rate.

Koshy et al (1993) applied theoretical modeling of the electrode and work piece system. In their studies, the velocity distributions of dielectric and molten metal were surveyed using EDM with a rotational disk electrode.

Kunieda et al (2000) reported that the MRR can be substantially increased with reduced EW using a multi-electrode discharging system.

Kao et al (2001) reported the parameter optimization of the electrical discharge machining process to Ti–6Al–4V alloy considering multiple performance characteristics using the Taguchi method and grey relational analysis. Performance characteristics including the electrode wear ratio, material removal rate and surface roughness are chosen to evaluate the machining effects. The optimized process parameters simultaneously leading
to a lower electrode wear ratio, higher material removal rate and better surface roughness are then verified through a confirmation experiment.

Kuo-Ming Tsai et al (2001) established several surface models based on neural networks taking the effects of electrode polarity into account. They subsequently developed a semi-empirical model, which dependant on the thermal, physical and electrical properties of the work piece and electrode together with pertinent process parameters. It was noted that the model produces a more reliable surface finish for a given work under different process conditions.

Keith Hargrove et al (2007) developed a finite element method program for temperature distribution in the work piece under the condition of different cutting parameters. The low carbon steel was selected to test the simulation on thermal parameters. The thickness of the temperature affected layers for different cutting parameters is computed based on the critical temperature value. The thickness of temperature-affected layers is minimized by selection of certain cutting speed and also sets of cutting process parameters are determined for manufacturer.

Kim et al (2007) investigated the effect of a magnetic field on electrolytic finishing process associated with the migration of ions. Their findings revealed that the migration path of the electrolytic ion could be changed by the magnetic field. In addition, the surface finishing effects could be improved to obtain a high quality of surface integrity effectively and quickly.

Kuppan et al (2008) investigated the influence of EDM process parameters in deep hole drilling of Incronel 718. The results showed that the MRR is more influenced by peak current, duty factor and electrode rotation,
where as surface roughness is strongly influenced by peak current and pulse on time.

Khan (2008) studied and analysis has been done to evaluate the electrode wear along the cross-section of an electrode compared to the same along its length during EDM of aluminum and mild steel using copper and brass electrodes. In an overall performance comparison of copper and brass electrodes, the author found that electrode wear increases with an increase in both current and voltage, but wear along the cross-section of the electrode is more compared to the same along its length.

Kodalagara et al (2010) presented the formulation and solution of optimization of various process parameters for the selection of the best control settings on a microwire electrical discharge machining process. A factorial design model was used to predict the measures of performance as a function of various control settings. Analysis of variance is used to indicate the significant factors. Regression models relating the machining performance are established. The performance measures taken for the model are material removal rate (MRR), over cut and surface roughness.

Lauwers et al (1998) developed a control system to reduce the risk of wire rupture based on a thermal model. The model is used to perform an on-line calculation of the temperature distribution over the wire electrode.

Lin et al (2000) optimized the process parameters for taking various performance measures of EDM process by using Taguchi method and fuzzy logic. Liao et al (2002) established the mathematical models relating the machining performance by using regression analysis. Based on the mathematical models developed, the objective functions are obtained. A feed forward neural network has been used to associate the cutting parameters with the cutting performance. A simulated annealing algorithm is then applied to
the neural network for solving the optimal cutting parameters based on a performance index within the allowable working conditions. In the past few decades, a few EDM modelling tools correlating the process variables and surface finish have been developed.

Lee et al (2003) developed a gain self-tuning fuzzy control system to cope with the conditions that often occur with wire rupture in the WEDM process, such as an improper setting of machining parameters, machining the work piece with varying thickness, etc. Experimental results of several cases show that the proposed controller results in a satisfactory performance. As a result, wire rupture problems in most WEDM processes can be successively solved by the proposed control strategy.

Ming Guo and Tsai (2002) focused on optimum processing of BaTiO semi-conducted material. They developed a model by DOE methods and further worked on an optimization model by using genetic algorithms.

Mohan et al (2002) investigated the effects of EDM hole drilling parameters of aluminium alloys and the results of the study have revealed that a rotating electrode has a positive effect with MRR, Electrode Wear (EW) and surface integrity than a stationary electrode. The authors further investigated the MRR, EWR, and surface roughness (SR) for evaluating machinability of aluminum silicon carbide composites. They found that the pulse duration has an inverse effect on all response variables such as MRR, EWR, and SR.

Mathew et al (2007) conducted statistical based experimental investigation to analyze the effect of different process parameters on over cut in the microslots produced using µ-WEDM operation with transistor circuit on aluminum and stainless steel and revealed that the dominant process parameters influencing the machining performance were gap voltage, resistance, and pulse on-time.
Mahapatra et al (2007) studied the relationship between control factors and responses like MRR, SF and kerf by means of nonlinear regression analysis, resulting in a valid mathematical model. Finally, genetic algorithm, a popular evolutionary approach, is employed to optimize the wire electrical discharge machining process with multiple objectives. The study demonstrates that the WEDM process parameters can be adjusted to achieve better metal removal rate, surface finish and cutting width simultaneously.

Mohammad et al (2007) investigated the effect of ultrasonic vibration of the tool in the process of electrical discharge machining. The ultrasonic vibration of the tool has significant effect on the dynamic behaviour of the vapour bubble generated between the tool and the work piece due to the electrical discharge. The experimental results also show that the rate of material removal in the case of shorter pulse on-time is higher. It should be noted that if the machining parameters are set up properly and if the frequencies of the electrical discharge and the tool vibration are synchronized, the electrical discharge between the tool and the work piece most likely occurs in the closest position of the tool to the work piece. From the numerical results it is predicted that in such a case the vibration of the tool significantly increases the material removal rate in ultrasonic assisted EDM.

Mohammad Jafar Haddad et al (2010) developed Cylindrical Wire Electrical Discharge Turning (CWEDT) process to generate precise cylindrical forms on hard, difficult to machine materials. A precise, flexible, and corrosion-resistant submerged rotary spindle was designed and added to a conventional five-axis CNC wire Electrical Discharge Machine (EDM) to enable the generation of free-form cylindrical geometries. In this study, the effect of machining parameters on surface roughness (Ra) and roundness in cylindrical CWEDT of a AISI D3 tool steel was investigated. In addition, power, pulse off time, voltage, and spindle rotational speed are adopted for
evaluation by using full factorial design of experiments. Cross sections of the EDM parts were examined using the SEM and micro hardness tests to quantify the sub-surface recast layers and heat-affected zones under specific process parameters.

Nilesh et al [ ] focused on experimental investigation to examine the effect of electrical as well as non-electrical machining parameters on performance in wire electro discharge machining of metal matrix composites (Al/Al2O3p). Taguchi orthogonal array was used to study the effect of combination of reinforcement, current, pulse on-time, off time, servo reference voltage, maximum feed speed, wire speed, flushing pressure and wire tension on cutting speed, surface finish, and kerf width. Reinforcement percentage, current, and on-time was found to have significant effect on cutting rate, surface finish, and kerf width. The optimum machining parameter combinations were obtained for surface finish, cutting speed, and kerf width separately.

Oguzhan Yilmaz et al (1991) presented a comparative experimental investigation of EDM fast hole of aerospace alloys, namely Inconel 718 and Ti-6Al-4v. A series of experiments was carried out using EDM process in order to explore the influence of electrode type and material i.e. Single and multi channel tubular electrodes made of brass and copper materials. The experimental result revealed that the single channel electrode has comparatively better material removal rate and lower electrode wear rate. In addition multi channel electrodes produced comparatively lower hardness values. The effect of other important parameters like current, voltage, and machining time on TWR, SR, over cut and hardness is not considered.

Patil and Brahankar (2006) investigated the performance of Al/SiCp composites with wire electro-discharge machining. They studied the effect of various control parameters such as pulse on-time, off-time, ignition pulse current, wire speed, wire tension, and flushing pressure on cutting speed and surface finish in WEDM of Al/SiCp composite. Taguchi method was used for experimental design. Based on experimental results, mathematical models relating the machining performance and machining parameters were developed. Optimal settings for each performance measure have also been investigated.

Probir Saha et al (2008) developed a second order multi-variable regression model and a feed-forward Back-Propagation Neural Network (BPNN) model to correlate the input process parameters, such as pulse on-time, pulse off time, peak current, and capacitance with the performance measures namely, cutting speed and surface roughness while Wire Electro-Discharge Machining (WEDM) of tungsten carbide-cobalt (WC-Co) composite material. It is observed that the regression model is quite comparable to BPNN for cutting speed prediction. The proposed neural network model and regression model for this process can also exhibit the parametric effect on the cutting speed and surface roughness. It has also been seen that the increase in both peak current and capacitance lead to the increment of cutting speed and surface roughness within the range under investigation.

Probir Saha (2009) studied wire electro-discharge machinability of 5 vol% TiC/Fe in situ metal matrix composite (MMC). Four input process parameters such as pulse on-time, pulse off-time, wire feed rate, and average gap voltage have been considered, while cutting speed and kerf width have been considered as the measure of performance of the process.
Promod Kumar Patowari et al (2010) prepared a model of the surface modification phenomenon by EDM with artificial neural networks. Two output measures, material transfer rate and average layer thickness, have been correlated with different process parameters and presented in the form of plots. The predicted results are matching well with the experimental results.

Ponappa (2010) evaluated the effects of electrical discharge machining parameters on drilled-hole quality such as taper and surface finish. Experiments were conducted using Taguchi methodology to ascertain the effects of EDM process parameter. The process parameters such as pulse-on time, pulse-off time, voltage gap, and servo speed were optimized to get better surface finish and reduced taper. Confirmation tests were performed on the predicted optimum process parameters. Pulse-on time and the servo speed are identified as major response variables.

Qu et al (2002, 2002) developed the cylindrical WEDM process and investigation of surface integrity and mechanical property of EDM surface layer and showed that better material removal rate (MRR) could be achieved in cylindrical WEDM than in 2D wire EDM. Effects of the key parameters, wire feed rate, pulse on-time, and part rotational speed on the surface roughness and roundness were explored.

Quing GAO et al (2008) used artificial neural network and genetic algorithm to establish the parameter optimization model. An ANN model that adopts Levenberg- Mquardt algorithm has been set up to represent the relationship between material removal rate and input parameters, and GA is used to optimize the parameters. The model is shown to be effective and MRR is improved using optimized machining parameters.

However, Rajurkar and Wang (1991) made a significant observation that, for a thick work-piece material, wire rupture takes place
even without a sudden increase in the frequency/power values once the machining conditions cross the critical frequency/power level.

Reddy and Rao (2005) developed a mathematical model for surface roughness considering the cutting parameters and tool geometry during end milling of medium carbon steel using RSM. Ryu et al (2006) incorporated the effect of cutting edge angle on roughness and texture generation on end milled steel surfaces. They have used RMS deviation, skewness and kurtosis for evaluating the generated surface texture characteristics.

Ramakrishnan et al (2006) presented a multi response optimization method using Taguchi’s robust design approach is proposed for wire electrical discharge machining (WEDM) operations. Experimentation was planned as per Taguchi’s L16 orthogonal array. Each experiment has been performed under different cutting conditions of pulse on time, wire tension, delay time, wire feed speed, and ignition current intensity. Three responses namely material removal rate, surface roughness, and wire wear ratio have been considered for each experiment. Finally experimental confirmation was carried out to identify the effectiveness of this proposed method. A good improvement was obtained.

Routara et al (2009) investigated the influence of machining parameters, viz., spindle speed, depth of cut and feed rate, on the quality of surface produced in CNC end milling. The second-order mathematical models, in terms of the machining parameters, have been developed for each of these five roughness parameters prediction using response surface method on the basis of experimental results. The roughness models as well as the significance of the machining parameters have been validated with analysis of variance.
Reza et al (2010) optimized the individual machining characteristics for the injection flushing type of EDM process on SS 304 work piece using copper tool. Higher electrode wear rate (EWR) would give bad dimensional precision for the machined surface. Therefore to achieve optimum dimensional precision for the work piece, the quality characteristic for EWR is set lower. Taguchi method is used to analyze experimental results of EWR on machining characteristics.

Scott et al (1991) used a factorial design method to determine the optimal combination of control parameters in WEDM, the measures of machining performance being the metal removal rate and the surface finish. Based on the analysis of variance, it was found that the discharge current, pulse duration, and pulse frequency are significant control factors for both the metal removal rate and surface roughness.

Speeding et al (1997) developed response surface methodology (RSM) and artificial neural network (ANN) models for the WEDM process. The ANN model is found to fit the data better and have a higher predictive capability of surface roughness value Ra and cutting speed.

Shanmugam et al (2000) have considered face milling operation with the objective of minimizing total production cost. Genetic Algorithm based on real coding had been used and the optimum machining variables such as number of passes, depth of cut, speed and feed rate at each pass were determined.

Su et al (2004) reported the optimization of the EDM process parameters from the rough cutting stage to the finish cutting stage. A trained neural network was used to establish the relationship between the process parameters and machining performance. GA-based neural network can be
successfully used to generate optimal process parameters from the rough cutting stage to the finish cutting stage.

Saravanan et al (2005) proposed the non-traditional optimization techniques to find optimal parameters for continuous profile machining and the optimal results were compared and also best one is proposed.

Sarkar et al (2006) presented an attempt to develop an appropriate machining strategy for a maximum process criteria yield. A feed forward back-propagation neural network is developed to model the machining process. The three most important parameters – cutting speed, surface roughness and wire offset – have been considered as measures of the process performance. The model is capable of predicting the response parameters as a function of six different control parameters, i.e. pulse on time, pulse off time, peak current, wire tension, dielectric flow rate and servo reference voltage. Experimental results demonstrate that the machining model is suitable and the optimization strategy satisfied practical requirements.

Sohani et al (2009) presented the application of response surface methodology (RSM) for investigating the effect of tool shapes such as triangular, square, rectangular, and circular with size factor consideration along with other process parameters like discharge current, pulse on-time, pulse off-time, and tool area. The RSM-based mathematical models of material removal rate (MRR) and tool wear rate (TWR) have been developed using the data obtained through central composite design. The investigations revealed that the best tool shape for higher MRR and lower TWR is circular, followed by triangular, rectangular, and square cross sections.

Sathiskumar et al (2009) discussed the effect of wire electrical discharge machining (WEDM) parameters such as pulse-on time (TON), pulse-off time (TOFF), gap voltage (V) and wire feed (F) on material removal
rate (MRR) and surface roughness (Ra) in metal matrix composites (MMCs) consisting of aluminium alloy (Al6063) and silicon carbide (SiCp) is discussed. The Al6063 is reinforced with SiCp in the form of particles with 5%, 10% and 15% volume fractions. The experiments are carried out as per design of experiments approach using L9 orthogonal array. The results were analyzed using analysis of variance and response graphs.

Saradindu Das et al (2010) developed a comprehensive mathematical model to incorporate plasma features, moving heat source characteristics, multi-spark phenomenon, and wire vibrational effect to predict the cathode erosion rate for a single- and multi-spark in micro- WEDM. The experimental validation of the model shows that the trends predicted by the model are logical and match fairly well with the experimental trends.

Saradindu Das et al (2010) developed a comprehensive mathematical model to incorporate plasma features, moving heat source characteristics, multi-spark phenomenon, and wire vibrational effect to predict the cathode erosion rate for a single- and multi-spark in micro- WEDM. The erosion rate evaluated by the model shows dependence on variables like voltage, wire diameter, number of sparks, and wire vibration but is independent of the wire velocity. The experimental validation of the model shows that the trends predicted by the model are logical and match fairly well with the experimental trends.

Simul Banerjee et al (2010) investigated a one-dimensional explicit finite difference thermal model. This is proposed for estimating the transient temperature distribution along the length of the wire under the conditions of randomly located spatial sparks with and without the formation of clusters. The predicted values of maximum wire temperatures indicate the degree of wire rupture risk, which has been found to be different for short and long elapsed times. The effects of work-piece height, power input, pulse
frequency, duty factor, wire velocity, wire diameter, and the convective heat transfer coefficient have been reported. The one-dimensional thermal models may be used for setting rules of selection for an expert system for the safe operating conditions of wire electro-discharge machining.

Thiesen et al (1993) reported the most EDM conditions affecting on the surface integrity of titanium alloys using copper and brass electrodes. In order to optimize the performance characteristics of EDM on titanium based alloys.

Tzeng et al (2001) presented the effects of various powder characteristics on the efficiency of Electro Discharge Machining (EDM). The additives examined include aluminium (Al), chromium (Cr), copper (Cu), and silicon carbide (SiC) powders that have significant differences in their thermo physical properties. The machining mechanism with the addition of the foreign particles, the tool wear rate (TWR), and the material removal rate (MRR) have been investigated. The addition of copper powder to the dielectric fluid was found to make almost no difference to the pure kerosene EDM system.

Tosun et al (2003) investigated the effect of cutting parameters on size of erosion craters (diameter and depth) on wire electrode were experimentally and theoretically investigated in wire electrical discharge machining. The experiments were conducted under the different cutting parameters of pulse duration, open circuit voltage, wire speed and dielectric flushing pressure. Brass wire of 0.25 mm diameter and AISI 4140 steel of 0.28 mm thickness were used as tool and work piece materials in the experiments. It is found that increasing the pulse duration, open circuit voltage, and wire speed increases the crater size, whereas increasing the dielectric flushing pressure decreases the crater size.
Then, Tzeng and Chen (2007) reported the application of fuzzy logic analysis coupled with Taguchi methods to optimize the precision and accuracy of the high-speed EDM process.

Tomadi et al (2009) studied the influence of operating parameters of tungsten carbide on the machining characteristics such as surface quality, MRR and electrode wear. The optimized values are validated by the conducting experiments. MRR and EWR in this experiment were calculated by using mathematical method. The result of the experiment was collected and analyzed using STATISTICA software.

Uno et al (1996) reported on the bottom profile of a groove machined using EDM with a rotational disk electrode in carbon tool steel SK3. Among those studies, little work was found using an EDM with a rotary disklike electrode on Maximum Material Composite (MMC). This technique has not been generally applied, possibly owing to the limitations of EDM itself. The conventional EDM technique lacks axial rotation during machining.

Vijayakumar et al (2003) have proposed a new non-traditional technique based on Ants Colony algorithm for solving multi-pass turning optimization problems.

Valentincic et al (2004) attained high MRR, low EWR and smooth surface finish in EDM, a stable machining process is required which is partly influenced by the contaminate on the gap between the work piece and the electrode and it also depends on the size of the eroding surface.

Vamsi Krishna pasam et al (2010) experimentally studied parameters of WEDM on titanium alloy. The behaviour of eight control parameters such as ignition pulse current, short pulse duration, time between
two pulses, servo speed, servo reference voltage, injection pressure, wire speed and wire tension on surface finish was studied using Taguchi parameter design. Optimum control parameters values are proposed for the selected work piece.

Wang (1998) has presented an optimization analysis, strategy and CAM software module for the selection of economic cutting conditions in single-pass end milling on CNC machines.

Wang et al (2000) investigated the direct effect on EDM performance such as MRR, Electrode Wear (EW) and surface integrity. Optimum EDM drilling parameters can be obtained with properly selected electrode type and materials.

Yahn et al (2000) optimized the cutting of Al2O3/6061Al composite using rotary electro-discharging machining (EDM) with a disklike electrode by using Taguchi methodology. The Taguchi method is used to formulate the experimental layout, to analyse the effect of each EDM parameter on the machining characteristics, and to predict the optimal choice for each EDM parameter. Four observed values, MRR, EWR, REWR, and SR, were used to verify this optimisation of the machining technique. In addition, six independent parameters were chosen as variables in evaluating the Taguchi method.

Yan et al (2001) developed a novel process of magnetic-force-assisted electrical discharge machining (EDM) and conducted an experimental investigation to optimize the machining parameters associated with multiple performance characteristics using gray relational analysis. The machining parameters of magnetic-force-assisted EDM could be optimized for multiple performance characteristics. Moreover, MRR, EWR, and SR
were greatly improved when the machining parameters were set at the optimal levels.

Yan et al (2003) presented a WEDM adaptive control system that maintains optimal machining and improves the stability of machining at the stair section where work piece thickness changes. A three-layer back propagation neural network is used to estimate the thickness of a work piece. The developed adaptive control system is executed in the hierarchical structure of three control loops, using fuzzy control strategy. The developed adaptive control system results in faster machining and better machining stability than does the commonly used gap voltage control system.

Yan et al (2003) developed a different prototype micro-WEDM system with a new architecture for wire transport to get a smooth wire transport and constant tension across the wire.

Yusuf Keskin et al (2006) studied the performance of the experiments by determination of parameters affecting surface roughness. The data obtained for performance measures have been analyzed using the design of experiments methods. A considerably profound equation is obtained for the surface roughness using power, pulse time, and spark time parameters. Effects of machining parameters on the surface roughness values of machined components by EDM have been investigated experimentally. It is apparent that the surface roughness has an increasing trend with an increase in the discharge duration.

Aidarov (1965) used a similar probabilistic method in evaluating the probability of number of atoms hitting a region to estimate the number of sparks based on the intensity of spectral line.
Zakharov et al (1972) used a probabilistic method to evaluate the number of sparks based on finding error in the homogeneity of spectral distribution. Zakharov and

2.3 LIMITATIONS OF THE EXISTING RESEARCH

Based on the above literature review, the following limitations were identified and needs attention:

- In earlier research work, the newer materials are not investigated. (incolloy 650 & inconel601 which are used in aero space industry)
- Deep hole drilling by EDM is not dealt by many researchers.
- Material Removal Rate (MRR) has been widely used as objective function. Surface roughness was not dealt by many researchers.
- More emphasis was towards tool and die making i.e., Oil Hardened Steel (OHS).
- Brass is used as a wire electrode in WEDM by many researchers.
- Standard Electrodes like copper, Brass are used by many researchers.
- Optimization of EDM and WEDM are concentrated by very few researchers.
2.4 NEED FOR FURTHER RESEARCH

The current state of research indicates a potential scope for research on the machining operations. Based on the literature review, the following are emphasized:

- Experimental analysis on incolloy 650, inconel718 and Die steel are to be incorporated.
- Deep hole drilling by EDM is to be experimentally analyzed.
- Tungsten and composite electrodes are to be used for investigation.
- Optimization of EDM and WEDM needs to be focused.
- Thermal analysis needs more attention.
- Need to implement robust optimization tools which yield global optima.