CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

EDM is one of the pioneering technologies for machining metal matrix composites, on which research attempts are being made around the world in the engineering community to explore its potential. After going through related literature, the survey is broadly classified into three different categories such as

(i) Machining performance and Process optimization

(ii) Grey relational analysis and

(iii) ANN modeling

2.2 MACHINING PERFORMANCE AND PROCESS OPTIMIZATION

Ramulu & Taya (1989) investigated machinability of 15 vol.% and 25 vol.% SiC whisker/2124 aluminum matrix (SiCw/Al) composite. The material samples were cut at coarse, medium, and fine conditions using copper and brass tools. It was found that material removal rate increases with increase in power of electrode. MRR in 15 vol.% SiCw/2124 Al is >25 vol.% SiCw/2124 Al. Material removal rate obtained by using copper electrode is 5-10% less than that of obtained when using brass electrode. Machining time appears to be higher in 25 vol.% SiCw/Al than in 15% SiCw/Al composite.
The micro-hardness tests on SiCw/Al composite have revealed that the machining causes surface softening at slower cutting speed. It was also found that higher cutting speed results in micro-damage in the surface and sub-surface area.

Soni & Chakraverti (1993) experimented with rotary electrode discharge machining to study the machining characteristics of titanium alloy. To clear the debris effectively from the gap between the electrodes in EDM, the tool was given rotary motion at 500, 750 and 1000 rpm. Experimental investigations were made in respect of metal removal rate electrode wear rate relative electrode wear and surface roughness with a rotating copper-tungsten tool electrode. Compared with a stationary electrode, i) the MRR improved with the rotating electrode due to improved flushing action and sparking efficiency; However the surface was higher ii) the MRR was better in through hole machining than in blind-hole machining at all rotational speeds iii) the tool wear rate increased with increasing speeds but the wear ratio was not significantly affected and iv) electrode corner wear and hole corner radius in blind hole machining were lower with the rotating electrode.

Philip Koshy et al (1993) suggested when the provision of holes in the electrode is impracticable, flushing of the working gap poses a major problem. Use of a rotating disk electrode was proposed as a more productive and accurate technique than use of a conventional electrode. Material removal rate, tool wear rate, relative electrode wear, corner reproduction accuracy, and surface finish aspects of a rotary electrode were compared with those of a stationary one. The effective flushing of the working gap brought about by the rotation of the electrode remarkably improved material removal rate and machines surfaces with a better finish.
Hung et al (1994) investigated the feasibility of applying electrical discharge machining process for cast aluminum MMC reinforced with silicon carbide particles. Statistical models of the process were also developed to predict the effect of process parameters on metal removal rate, re-cast layer, and surface finish. It was found that the presence of SiC particles results in reduced MRR. This is because these particles shield the aluminum matrix and protect it from being vaporized. The unmelted SiC particles drop out from the composite material together with surrounding molten aluminum droplets.

While some aluminum droplets were flushed away by the dielectric, others trap the loosened SiC particles then re-solidify onto the surface to form a re-cast layer (RCL). No crack was found in the RCL and the softened heat-affected zone, which was below the RCL. It was reported that MRR and depth of recast layer is mainly controlled by input power and the current alone dominates the surface finish of machined surface. The study was detailed in nature and particularly investigated the effect of variation in process parameters on performance measures. Explanation of formation phenomenon of recast layer and its properties were additional information.

Hocheng et al (1997) made a preliminary study of MRR of SiC/Al composite. Heat conduction model was applied to interpret correlation between the major machining parameters such as electrical current, pulse duration, and crater size produced by single spark for the representative material SiC/Al. Material removal characteristics of single and continuous discharge were investigated. The study starts from single discharge and relationship between crater size and set discharge parameters was found. Two heat conduction models were used to calculate crater size formed in a single discharge and results were compared with experimental data. The experimental results follow very well with finite step source heat conduction model. The material removal rate was found proportional to the applied
current and on-time. The crater size of SiC/Al was also compared with that of steel and found larger than that. In the continuous discharge analysis, one finds the discharge of SiC/Al was more irregular and the material removal rate is faster at the beginning followed by being retarded due to the existence of SiC particles in the gap. As closed-loop gap control was applied, the material removal rate was greatly improved as expected. For effective machining of SiC/Al, large current and short on-time is recommended.

Che Chung Wang & Biing Hwa Yan (2000) worked on optimizing the blind hole drilling of Al2O3/6061 Al composite using rotary electrode discharging machining by using Taguchi methodology. Experimental results confirmed that copper electrode with an eccentric through hole using injection flushing performed in the best way compared to stationary solid electrode and rotary solid electrode with injection flushing. Three observed values, MRR, EWR and SR verified this optimization of the machining techniques. Analysis of the Taguchi method revealed that the electrical parameters were more significant than the non electrical parameters on the machining characteristics. It was found that either the polarity or the peak current most prominently affected the MRR, SR or EWR. Also semi empirical equations were derived that contained all the machining characteristics.

Muller & Monaghan (2000) presented details and results of an investigation into the machinability of SiC particle reinforced aluminum matrix composites using different non-conventional machining processes such as electro discharge machining, laser cutting and abrasive water jet. Objective of the research work was to investigate difference in surface quality, including surface roughness, surface topography, and sub-surface damage of machined work-piece. Furthermore, the effect of the reinforcement on the machining operation was investigated by performing comparative tests on non-reinforced aluminum alloy samples. The results
obtained indicate that Al/SiC particle reinforced metal matrix composite (PRMMC) was machinable by using same non-conventional machining processes. The findings show that EDM process was suitable for machining PRMMCs, but the process was very slow. Machining results in a crater-like surface. The size of the craters increased with increased discharge energy. Also, relatively small amount of sub-surface damage was found on the cut surfaces after machining (depending on the chosen machining settings).

Ghoreishi & Atkinson (2002) made a comparative experimental study of machining characteristics of tool and die steel AISI 01 in vibratory, rotary and vibro-rotary electrode discharge machining. The effects of high and low frequency forced axial vibration of the electrode, rotation of the electrode and combinations of these methods in respect of material removal rate, tool wear rate and surface roughness in die-sinking electro discharge machining were analyzed and compared. Comparison was made to establish which combinations were most appropriate to different machining regimes (finishing, semi-finishing and roughing). In the finishing regime, a combination of high frequency vibration and rotation of the electrode was beneficial and gave the best results in comparison with pure EDM, rotary EDM and vibratory EDM. In the semi-finishing regime, vibro-rotary EDM increases MRR by upto 35% of that obtained with vibratory EDM and by upto 100% compared with rotary EDM. In the roughing regime, pure EDM does not require other combinations of motion in order to improve flushing or energy discharge.

Mohan et al (2002) evaluated the machining feasibility of Al-SiC composites. The objective was to investigate influence of process parameters, electrode material, and volume percentage of SiC particle on performance measures. Electrode polarity, discharge current, pulse duration, and electrode rotation were taken as parameters. Al-20% SiC and Al-25% SiC composite
samples were taken for study. Copper and brass were selected as electrode material. Several conclusions were made based on experimental results. The MRR was found high with positive polarity and increased with increase in current. It was more with brass electrode in comparison with copper electrode. The increase of either the pulse duration or volume percentage of SiC results in decrease in MRR and it increased with increase in rotational speed. The TWR was less when volume percentage of silicon carbide particle was less and increased with increase in current. The surface roughness value decreased with decrease in pulse current and increased with increase in volume percentage of SiC. The study optimized process parameters for different volume percentage of SiC and electrodes for maximum MRR.

Puertas & Luis (2003) made a study on the machining parameters optimization of electrical discharge machining the study was mainly focused on aspects related to surface quality and dimensional precision. Regression modeling of the roughness average (Ra) and roughness quadratic average (Rq) in the function of current (I), pulse on time (ti) and pulse off time (to) were carried out. Soft steel (F1110) was the work material and prismatic electrode made of copper with a square cross section of 25 x 25mm was used in the experiments. Design of experiments was used for the analysis and a full factorial design type 23 with four central points was selected in order to carry out this study. It was observed that current was the most important factor influencing surface roughness and there was a strong interaction between I and ti.

Ho & Newman (2003) reported the introduction of EDM to the metal cutting has been a viable machining option of producing highly complex parts, independent of the mechanical properties of work piece material. Controlling the EDM process mostly relied on empirical methods largely due to the stochastic nature of the sparking phenomenon involving
both electrical and non-electrical process parameters. The EDM process needs to be constantly revitalized to remain competitive in providing an essential and valuable role in the tool room manufacturing of part with difficult-to-machine materials and geometries.

Narender Singh et al (2004) worked on Al-10%SiCp as-cast metal matrix composites. The objective of the work was to investigate the effect of current, pulse on-time and flushing pressure on metal removal rate, tool wear rate, taper, radial overcut, and surface roughness of machined material. Many conclusions were drawn by experimentation. MRR was found higher for larger current and pulse on-time settings at the expense of taper, radial overcut, and surface finish. Electrode wear was also found to be higher, even larger than the material removal rate for larger current settings. The dimensional accuracy was affected at higher current and pulse on-time ratings. Both material removal rate and electrode wear were considerably influenced by flushing pressure. Two more performance measures radial overcut and taper were taken into account along with three major performance measures.

Mohan et al (2004) investigated the machining characteristics of SiC/6025 Al composite using rotary electro-discharge machining with a tube electrode. The objective of research work was to investigate effects of discharge current, pulse duration, SiCp percentage, tube electrode hole diameter, and speed of electrode rotation on performance measures. Also, mathematical modeling and parameter optimization was performed for experimental results. Many conclusions were drawn from their study. The effect of drilling with the rotating tube electrode resulted in higher material removal rate than the rotating solid electrode. The electrode tube hole diameter significantly affected the performance measures. The MRR and SR improve with the decrease in hole diameter but electrode wear increased. The
increase in volume percentage of SiC has resulted in decrease in material removal rate, surface roughness, and increase in electrode wear. The increase in rotational speed of the tube electrode produced higher material removal rate, electrode wear, and better surface quality. The material removal rate and electrode wear were higher for the injection flushing than the side flushing.

Bala Murugan Gopalsami et al (2009) applied Taguchi method and ANOVA for process parameters optimization of hard machining while machining hardened steel. A L18 array, signal-to-noise ratio and analysis of variance (ANOVA) were applied to study performance characteristics of machining parameters (cutting speed, feed, depth of cut and width of cut) with consideration of surface finish and tool life. SEM pictures indicated that chipping and adhesion were the main causes of wear. Results obtained by Taguchi method closely matched with ANOVA. Cutting speed was the most influencing parameter corresponding to quality characteristic of tool life and surface finish. Further multiple regression equations were formulated for estimating predicted values of surface roughness and tool wear rate for a specified range.

Oguzhan Yilmaz &Ali Okka (2010) analysed the effect of single and multi channel electrodes application on EDM fast hole drilling performance. The work materials were Inconel 718 and Ti-6Al-4V. Single and multichannel tubular electrode made of brass and copper were used as electrodes. The experimental results revealed that the single channel electrode had comparatively better material removal rates for both the alloys. Brass electrode material was more efficient in terms of obtaining better material removal rate. For Ti-6Al-4V alloy, lower electrode wear is observed in copper single and copper multi channel electrode where as for Inconel 718 the lowest electrode wear was observed for brass single channel electrode. However SEM images showed that multichannel electrodes produced better surfaces
than single channel electrodes for both aerospace alloys. The main reason was supposed to be the flushing effect of the multichannel electrodes that properly removed the debris away stabilized the repetition of charges and controlled the immediate resolidification of the melted zones. Microstuctural changes while drilling operations for both the types of electrodes resulted in an annealing effect on Inconel 718 and a tempering effect on Ti-6Al-4V alloy. In addition multichannel electrodes produced comparatively lower hardness values.

Velmurugan et al (2014) investigated the effect of parameters like Current(I), Pulse on time(T), Voltage(V) and Flushing pressure(P) on metal removal rate (MRR), tool wear rate (TWR) as well as surface roughness(SR) on the machining of hybrid Al6061 metal matrix composites reinforced with 10% SiC and 4% graphite particles. Composite was fabricated using stir casting process. A central composite rotatable design was selected for conducting experiments. Mathematical models were developed using the MINITAB R14 software. The method of least squares technique was used to calculate the regression coefficients and Analysis of Variance (ANOVA) technique was used to check the significance of the models developed. Scanning Electron Microscope (SEM) analysis was done to study the surface characteristics of the machined specimens and correlated with the models developed.

2.3 GREY RELATIONAL ANALYSIS

Lin & Lin (2002) used a new approach for the optimization of the electrical discharge machining (EDM) process with multiple performance characteristics based on the orthogonal array with the grey relational analysis. A grey relational grade obtained from the grey relational analysis was used to
solve the EDM process with the multiple performance characteristics. Optimal machining parameters were then determined by the grey relational grade as the performance index. In this study, the machining parameters, namely work piece polarity, pulse on time, duty factor, open discharge voltage, discharge current, and dielectric fluid were optimized with considerations of multiple performance characteristics including material removal rate, surface roughness, and electrode wear ratio. Cylindrical pure copper with a diameter of 8mm was used as an electrode to erode a work piece of SKD 11 alloy steel with a diameter of 12 mm. kerosene with aluminium oxide powder was used as a die electric fluid. A L18 orthogonal array was used and 18 experiments were conducted with 3 repetitions. Grey relational analysis was carried out for the experimental results and optimal machining parameters were determined based on grey relational grade.

Thus the optimization of complicated multiple performance characteristics can be converted into optimization of single grey relational grade. The analysis of variance (ANOVA) was then carried out to investigate which machining parameters significantly affect the performance characteristic. This was accomplished by separating the total variability of the grey relational grades, which was measured by the sum of the squared deviations from the total mean of the grey relational grade, into contributions by each machining parameter and the error. Once the optimal level of the machining parameters is selected, the final step is to predict and verify the improvement of the performance characteristic using the optimal level of the machining parameters.

By confirmation tests it was clearly shown that the multiple performance characteristics in the EDM process were greatly improved through this study. The research work focused on parameter optimization by
applying grey theory. Grey analysis provides excellent solution to uncertain, multi-input, and discrete data problems. Since EDM process is of similar nature, therefore, the method is highly useful in parameter optimization of such experimental work.

Narender Singh et al (2004) optimized EDM parameters on machining Al–10%SiCP composites by grey relational analysis. The multi-response optimization of the process parameters viz., metal removal rate, tool wear rate, taper, radial overcut, and surface roughness on electric discharge machining of Al-10%SiCp as cast metal matrix composites using orthogonal array with gray relational analysis was reported. Orthogonal array with gray relational analysis was employed to optimize the multi-response characteristics of machining of Al-10%SiCp composites.

A L27 orthogonal array was selected and experiments were conducted with one repetition. In this study, ELEKTRAPULS spark erosion machine was used to carry out the experiments. Brass electrode of Ø 2.7mm was selected to drill holes in the components. Commercial grade kerosene was used as the dielectric fluid and side injection of the dielectric fluid was opted. The experimental result for the optimal setting showed that there was considerable improvement in the process. The application of this technique converts the multi-response variable to a single-response gray relational grade and, therefore, simplifies the optimization procedure.

Jong Hyuk Jung & Won Taw Kwon (2010) used Grey relational analysis for optimization of EDM parameters in machining micro-hole to a minimum diameter and maximum aspect ratio. They obtained optimum conditions of the machining parameters to machine a micro-hole of 40μm average diameter and an aspect ratio of 10 by using the Grey relational
analysis. MRR increased with increase in current and better with brass electrode. Machining time appeared to be higher in 25 vol.% SiCw/Al than in 15% SiCw/Al composite.

2.4 ANN MODELING

Abeesh Basheer et al (2008), created an ANN model for surface roughness in precision machining of metal matrix composites. In this model, a variation of the standard BP algorithm by using the Levenberg-Marquardt algorithm was used for training the system with 5-8-1 network configuration. Transigmodal transfer function was used because of its symmetric nature. The predicted response of the ANN model was in very good agreement with the experimental data (correlation coefficient of 0.977 and the mean absolute error of 10.4%).

Muthukrishnan & Paulo Davim (2009) used ANN to predict the surface roughness of metal matrix composites in addition with ANOVA. ANOVA and ANN approach provide a systematic and effective methodology for optimization. A 3-layered multilayer perceptron using back propagation algorithm was used in the network with 3-10-1 configuration. This method found to have prediction potentials for non-experimental pattern too. ANN methodology consumed lesser time giving high accuracy. (average error of 1.47%)

Krishna Mohana Rao et al (2009) developed a hybrid model using ANN and genetic algorithm to model and optimize surface roughness in electrical discharge machining of Ti6Al4V, HE15, 15CDV6 and M-250 by A 4-4-1 network configuration was found as the best structure. Multilayer perceptron with hyperbolic tangent activation function was used to train the
network. Good agreement between the neural predictions and experimental verification was demonstrated.

Mohan Kumar Pradhan & Chandan Kumar Biswas (2010) created Neuro-fuzzy and ANN models for prediction of MRR, TWR and radial overcut in die sinking EDM. Although both the models were found to be in good agreement with the experimental results, ANN was found to converge much faster.

Venkat Rao et al (2014) successfully used a neural network (4-14-8-3) to learn the collected experimental data by to predict the surface roughness, tool wear and work piece vibration. The ANN was trained with 54 examples, validated with 15 examples and tested with 8 examples. It was found that there is agreement between experimental data and predicted values for surface roughness (4.5185% of error), work piece vibration (4.2568% of error) and tool wear (2.9237% of error).

Then it was possible to change the cutting tool at correct time in order to get good quality of products. The neural network helped in selection of proper cutting parameters to reduce tool vibration and tool wear and reduce surface roughness.

2.5 SUMMARY OF LITERATURE REVIEW

Literature review on Machining performance and Process optimization, ANN modeling and Grey relational analysis can be summarized in the form of table is shown in Table 2.1.
### Table 2.1 Summary of Literature Review

<table>
<thead>
<tr>
<th>S.no</th>
<th>Author &amp; Year of Publication</th>
<th>Parameters/Machining process considered</th>
<th>Chief Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ramulu and Taya (1989)</td>
<td>Current, work piece and electrode materials</td>
<td>MRR increased with increase in current and better with brass electrode than copper. Machining time appears to be higher in 15 vol.% SiCw/Al than in 25 vol.% SiCw/Al composite.</td>
</tr>
<tr>
<td>2</td>
<td>Soni and Chakraverti (1993)</td>
<td>Current, Electrode rotations, On pulse duration</td>
<td>MRR improved with the rotating electrode. MRR was better in through hole machining than in blind hole machining. Increase in speed resulted in increase in tool wear rate.</td>
</tr>
<tr>
<td>3</td>
<td>Philip Koshy et al. (1993)</td>
<td>Electrode type, rotation of electrode and gap flushing</td>
<td>The effective flushing of the working gap brought about by the rotation of the electrode remarkably improved material removal rate and machines surfaces with a better finish.</td>
</tr>
<tr>
<td>4</td>
<td>Hung et al. (1994)</td>
<td>Voltage, Current, On time and Off time</td>
<td>Feasibility of using EDM process for MMC’s was confirmed and the models based on 2 level factorial experiments were developed.</td>
</tr>
<tr>
<td>5</td>
<td>Ho et al. (1997)</td>
<td>Current and on time</td>
<td>For effective EDM of SiC/Al, large current and shorter on time were recommended.</td>
</tr>
<tr>
<td>6</td>
<td>Che Chung Wang and Biing Hwa Yan (2000)</td>
<td>Polarity, Peak current, pulse duration, voltage, rotational speed of electrode and dielectric fluid pressure</td>
<td>Electrical parameters more significantly affect the EDM machining process than the non electrical parameters. The polarity of the electrode largely affected either the MRR or the SR while the peak current mainly affected EWR.</td>
</tr>
<tr>
<td>7</td>
<td>Muller and Monaghan (2000)</td>
<td>EDM, Laser cutting, abrasive water jet machining</td>
<td>The EDM process is suitable for PRMMC’s but the process is very slow. Laser machining offers significant productivity advantages for rough cut off applications. Abrasive water jet machining is very suitable for rough cut applications.</td>
</tr>
<tr>
<td>8</td>
<td>Ghoreishi and Atkinson (2002)</td>
<td>Axial vibration of electrode, rotation of the electrode and combination of these.</td>
<td>The combination of ultrasonic vibration and electrode rotation leads to increases in MRR, TWR and SR.</td>
</tr>
<tr>
<td>9</td>
<td>Mohan et al. (2002)</td>
<td>Polarity, current, electrode and work piece material, pulse duration and rotation of electrode</td>
<td>MRR was more with positive polarity, increased with increase in current, more with brass than copper electrode, decreased with the increase of either pulse duration or volume percentage of SiC and it was more with increase in rotational speed. TWR was less when volume percentage of SiC particle was less and increased with increase in current. SR value decreased with decreased in pulse current and increased with increase in volume percentage of SiC particle.</td>
</tr>
<tr>
<td>10</td>
<td>Paetas and Luis (2003)</td>
<td>Current, On time and Off time</td>
<td>High current was used obtain better surface roughness due to a better arc stability.</td>
</tr>
<tr>
<td>11</td>
<td>Ho and Newman (2003)</td>
<td>Review of research work of die-sinking EDM</td>
<td>The complicated inter-relationship between the different optimized process parameters was a major factor contributing to the overall machining efficiency.</td>
</tr>
<tr>
<td>12</td>
<td>PNarender Singh et al. (2004)</td>
<td>Current, pulse on-time and flushing pressure</td>
<td>MRR was higher for larger current and pulse on-time at the expense of taper, radial overcut, and surface finish. Electrode wear was also found to be higher, even larger than the material removal rate for larger current settings.</td>
</tr>
<tr>
<td>13</td>
<td>Mohan et al. (2004)</td>
<td>Polarity, current, work piece material, pulse duration, hole diameter and rotation of tube electrode</td>
<td>MRR was higher in tube electrode than solid electrode at rotating condition. Decrease in tube hole diameter produced a better MRR, SR and higher EWR. Increase in percentage of SiC resulted in decrease in MRR, SR and higher EWR. Increase in speed of tube electrode resulted in higher MRR, EWR and SR.</td>
</tr>
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<td>S.no</td>
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<td>14</td>
<td>Bala Murugan Gopalsami et al (2009)</td>
<td>Cutting speed, feed, depth of cut and width of cut</td>
<td>Results obtained by Taguchi method closely matched with ANOVA. Cutting speed was the most influencing parameter corresponding to quality characteristic of tool life and surface finish.</td>
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<td>15</td>
<td>Oguzhan Yilmaz and Ali Okka (2010)</td>
<td>Work piece material, electrode type and material</td>
<td>Single channel electrode produces better MRR for both the alloys than multi channel electrode. Brass electrode produces better MRR than copper. Lower EWR is obtained with copper electrodes. Multichannel electrodes produced better SR.</td>
</tr>
<tr>
<td>16</td>
<td>Velmurugan et al (2014)</td>
<td>Current(I), Pulse on time(T), Voltage(V) and Flushing pressure(P)</td>
<td>MRR increased with increase in current, pulse on time and flushing pressure of the dielectric fluid while it decreased with increase in voltage. TWR increased with increase in current and voltage and it decreased with increase impulse on time and flushing pressure of the dielectric fluid. SR increased with increase in current, pulse on time, voltage and flushing pressure.</td>
</tr>
<tr>
<td>17</td>
<td>Lin and Lin (2002)</td>
<td>Work piece polarity, pulse on time, duty factor, open discharge voltage, discharge current and dielectric fluid</td>
<td>The optimization of complicated multiple performance characteristics viz., EWR, MRR and SR can be converted into optimization of single grey relational grade. Grey analysis provides excellent solution to uncertain, multi-input, and discrete data problems.</td>
</tr>
<tr>
<td>18</td>
<td>Narender Singh et al. (2004)</td>
<td>Current, pulse on time, flushing pressure</td>
<td>The multi-response optimization of the process parameters viz., metal removal rate, tool wear rate, taper, radial overcut, and surface roughness on electric discharge machining of Al-10%SiCp as cast metal matrix composites using orthogonal array with grey relational analysis was carried out.</td>
</tr>
<tr>
<td>19</td>
<td>Jong Hyuk Jung and Won Taw Kwon [2010]</td>
<td>Voltage, capacitance, resistance, the feed rate and a spindle speed</td>
<td>Optimum conditions of the machining parameters to machine a micro-hole of 40ȝm average diameter and an aspect ratio of 10 by using the Grey relational analysis.</td>
</tr>
<tr>
<td>20</td>
<td>Abeesh Basheer et al. (2008)</td>
<td>Volume and size of reinforcement, tool nose radius, feed rate, depth of cut</td>
<td>The predicted response (SR) of the ANN model was in very good agreement with the experimental data (correlation coefficient of 0.977 and the mean absolute error of 10.4%).</td>
</tr>
<tr>
<td>21</td>
<td>Muthukrishnan and Paulo Davim (2009)</td>
<td>Cutting speed, feed rate, depth of cut</td>
<td>ANN found to have prediction potentials for SR for non-experimental pattern too. ANN methodology consumed lesser time giving high accuracy. (average error of 1.47%)</td>
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<tr>
<td>22</td>
<td>Krishna Mohana Rao et al. (2009)</td>
<td>Work piece material, current, voltage</td>
<td>Hybrid models (ANN and GA) were developed for SR considering all the materials together which can predict the behavior of these materials when machining on EDM. The developed models were within the limits of agreeable error.</td>
</tr>
<tr>
<td>23</td>
<td>Mohan Kumar Pradhan and Chandan Kumar Biswas (2010)</td>
<td>Current, pulse duration, duty cycle and voltage</td>
<td>ANN, Sugeno and Mamdani system models for predicting MRR, TWR and radial overcut were found to be comparable in terms of the prediction accuracy and speed. The ANN network was in general converging much faster than the other two.</td>
</tr>
<tr>
<td>24</td>
<td>Venkat Rao et al. (2014)</td>
<td>Speed, nose radius and feed</td>
<td>The trained ANN was used to predict the surface roughness, tool wear and work piece vibration. It was found that there is agreement between experimental data and predicted values.</td>
</tr>
</tbody>
</table>
2.6 LITERATURE REVIEW FINDINGS AND SCOPE OF THE PRESENT WORK

Many researchers studied the influence of various process parameters such as polarity, pulse-on time, voltage, current, pulse-off time and flushing pressure on MRR, EWR and SR using EDM machine for a variety of materials including MMCs. The chief focus is on improving the MRR as it is directly related to the machining cost. Improvement in MRR was achieved by researchers by improving the flushing conditions. The flushing conditions were improved by providing rotary and /or vibratory motion to the tool and using tubular electrodes. Suitable mechanisms are necessary to achieve these motions which increase the cost of the EDM.

Oguzhan Yilmaz & Ali Okka only studied the performance using multichannel electrode in an EDM machine. Hence further studies are required to make the blind-hole sand study the performance using multichannel electrode in an EDM machine.

Single objective optimization was carried out by some researchers with Taguchi method and ANOVA for process parameters optimization. Results obtained by Taguchi method closely matched with ANOVA. Hence this method can be used in this research work.

Multi objective optimization was carried out by some researchers, by which optimization of two or more machining parameters can be obtained by assigning weights to each of the parameters. The results obtained were good and this method was also employed in this research work. The grey relational theory provides an efficient management upon the uncertain data, multi-input and discrete data. On the other hand, the GRA reveals the necessary information of the interactions among parameters. It provides a solution of a system in which the model is not sure or the information is
incomplete. Hence, analysis based on Taguchi method with GRA has been carried out to obtain significant process parameters and their optimal combination level for effective blind-hole drilling.

ANN providing a means for finding the response variables for all the different machining combinations was used by some researchers. Conducting experiments for all the machining combinations is time consuming and costly affair. Further, with ANN predicted results the optimum condition for each of the MRR, EWR and SR can be found out. The power of ANN in prediction of machining parameters was also used in this research work.

In this research work, use of the multichannel electrodes was carried out to improve the flushing conditions, which do not require any special mechanisms. With the existing EDM, these multichannel electrodes can be used to improve the MRR and ultimately reduce the machining cost.

The work piece material chosen was 15 % SiC particle reinforced Aluminium Metal matrix Composites (PAMCs). Ceramic reinforcements are generally oxides or carbides or borides ($\text{Al}_2\text{O}_3$, $\text{SiC}$ or $\text{TiB}_2$) and present in volume fraction less than 30% when used for structural and wear resistance applications. PAMCs are less expensive compared to continuous fiber reinforced aluminium metal matrix composites. Mechanical properties of PAMCs are inferior compared to whisker/short fiber/continuous fiber reinforced AMCs but far superior compared to unreinforced aluminium alloys.

Of the entire Aluminium Metal matrix Composites (AMC), PAMCs constitutes largest quantity of composites produced and utilized on volume and weight basis. PAMCs have been successfully used as components in automotive, aerospace, opto-mechanical assemblies and thermal management. Particle reinforced AMCs are in use as fan exit guide vane in the gas turbine
engine as ventral fins and fuel access cover doors in military aircraft. Particle reinforced AMCs are also used as rotating blade sleeves in helicopters. Flight control hydraulic manifolds made of 40 vol% SiCp reinforced aluminium composites have been successfully used. The most notable large size and high volume use of PAMCs is in braking systems of trains and cars. Presently AMC brake discs are extensively used in Railways and are in use in certain models of passenger cars. Potential automotive applications of PAMCs include valves, crankshafts, gear parts and suspension arms.

PAMCs are in use as recreational products including golf club shaft and head, skating shoe, base ball shafts, horseshoes and bicycle frames. AMCs containing high volume fraction ceramic particles are being used as microprocessor lids and integrated heat sinks in electronic packaging. They are also in use as carrier plates and microwave housing.

The optimal use of the EDM process for higher production rate with better accuracy demands proper control of machining parameters. Therefore, by controlling the various process parameters, optimal quality of the work piece can be obtained. However, till date, the findings available in the field of drilling of blind-holes using EDM with regard to optimization of process parameters are not adequate as there are no established optimal machining parameters. Thus, there is a great demand for extensive research of finding out the reliable and repeatable optimal combinational machining parameters. Taguchi method is very effective to deal with response influenced by multi-variables. This method focuses on minimizing the effect of causes of variation. In comparison with a traditional full factorial design of experiments, Taguchi’s methods in general, provide a significant reduction in the size of experiments thereby speeding up the experimental process. Two important techniques used in Taguchi design are OA’s and S/N ratios.