Abstract— Electrical Discharge Machining performance is generally evaluated on the basis of Material Removal Rate (MRR), Tool Wear Rate (TWR), Relative Wear Ratio (RWR) and Surface Roughness (SR). The important EDM machining parameters affecting to the performance measures of the process are discharge current, pulse on time, pulse off time, arc gap, and duty cycle [9]. A considerable amount of work has been reported by the researchers on the measurement of EDM performance on the basis of MRR, TWR, RWR, and SR for various materials. Several approaches are proposed in the literature to solve the problems related with optimization of these parameters. It is felt that a review of the various approaches developed would help to compare their main features and their relative advantages or limitations to allow choose the most suitable approach for a particular application and also throw light on aspects that needs further attention. In view of above, this paper presents a review of development done in the optimization of EDM related process parameters.

Keywords — EDM, MRR, EWR, SR, RSM, Taguchi.

I. INTRODUCTION

Electrical Discharge Machining (EDM) is an important manufacturing process for machining hard metals and alloys [2]. This process is widely used for producing dies, molds, and finishing parts for aerospace, automotive, and surgical components [3]. The process is capable of getting required dimensional accuracy and surface finish by controlling the process parameters [4]. EDM performance is generally evaluated on the basis of Material Removal Rate (MRR), Tool Wear Rate (TWR), Relative Wear Ratio (RWR), and Surface Roughness (SR) [3].

The important EDM parameters affecting to the performance measures of the process are discharge current, pulse on time, pulse off time, arc gap, and duty cycle [9]. In EDM, for optimum machining performance measures, it is an important task to select proper combination of machining parameters [13]. Generally, the machining parameters are selected on the basis of operator’s experience or data provided by the EDM manufactures. When such information is used during Electrical Discharge Machining, the machining performance is not consistent. Data provided by the manufacturers regarding the parameter settings is useful only for most commonly used steels. Such data is not available for special materials like Maraging steels, ceramics, and composites.

For these materials, experimental optimization of performance measures is essential. Optimization of EDM process parameters becomes difficult due to more number of machining variables and slight changes in a single parameter significantly affect the process.

Thus, it is essential to understand the influence of various factors on EDM process. Analytical and statistical methods are used to select best combination of process parameters for an optimum machining performance. Different author used different combination of process parameters. They analyze the experimental data by plotting interaction graphs, Residual plots for accuracy and Response curves. Some other methods used by different author for analysis of Taguchi’s DOE data related to Electrical Discharge Machining (EDM) and Wire Electrical Discharge Machining (WEDM) are Regression analysis, Response Surface Methodology, Central Composite Design (CCD), Feasible-Direction Algorithm, SA algorithm, Pareto, Artificial Bee Colony (ABC), Grey Relational Analysis, Genetic Algorithm, Fuzzy clustering, Artificial Neural Network, Tabu-Search Algorithm, Principle component method etc.

Most of the author used L27 Orthogonal Array. Generally the effect of Pulse ON time, Pulse OFF time, Spark gap set Voltage, Peak current, Flushing Pressure, Work piece height, wire tension and wire feed on the material removal rate, surface roughness, kerf and gap current is investigated.

II. VARIOUS TECHNIQUES FOR OPTIMIZATION OF EDM PROCESS PARAMETERS

The studies use several optimization techniques they may be classical or numerical based and have lead to evolved techniques used in modern technical scenario. After going through the literature the major optimization techniques and tools utilized by the researchers are as follows:

A. RSM Optimization Tools

B. Other Optimization Technique


III. ISSUES RELATED TO OPTIMIZATION OF EDM PROCESS PARAMETERS

The optimization process focuses on four vital components these are:

A. Input process parameters

Work Piece Material, Percentage Composition, Electrode Material, Peak Current, Discharge Current, Pulse on time, Pulse off time, Cutting Speed, Dielectric flushing pressure, Arc Gap, Duty Cycle, Taper Angle, Tool Shapes, Tool Area, Voltage, Rotational Speed of Electrode, Feed Rate, Pulse Frequency, Wire Speed, Wire Tension, Dielectric Flow Rate, Spark Gap Voltage, Axial–radial depth of cut, Machining Tolerance.

B. Process performances

Material Removal Rate (MRR), Tool Wear Rate (TWR), Relative Wear Ratio (RWR), and Surface Roughness (SR), kerf (width of cut), Dimensional deviations, Stability factor (Sf).

C. Work piece material

The materials investigated on WEDM generally of HSS and other Tool materials are Hot Die material, Cold Die material, Nickel alloys and Titanium alloys which are hard to compare to other material. These materials are AISI M2, AISI D2, AISI D3, AISI D5, AISI H11, AISI 4140, SKD 11, En16, En19, En31, En32, 1040, 2379, 2738, Inconel, Ti alloys, Al alloys, 7131 cemented, Tungsten Carbide (WC), Al 7075-B2C MMC, Titanium (grade-2), CK45 steel, EN-31 die steel, Inconel-600, High strength low alloy steel (HSLA), D2 tool steel (1.5%C, 12% Cr, 0.6%V, 1% Mo, 0.6% Si, 0.6% Mn and balance Fe), Al-SiC (20%), stainless steel AISI 304, medium carb on steel (EN8), Maraging steel (MDN 300), WPS DIN 1.2379/AISI D2 tool steel, AISI A2 tool steel, Maraging steel (MDN 250), WPS DIN 1.2379 tool steel, γ-TiAl, cryogenic-treated D-3 steel, SKD 61 steel, copper–steel (EN-8), Al2O3/6061Al composite etc.

D. Electrode material

The material used for electrode can be copper, brass, tungsten, graphite, steel, Copper–tungsten, copper–chromium alloy, haste alloy, molybdenum, chromium coated copper alloy, Brass-CuZn37, coated ceramic tool, Al–Cu–Si–TiC P/M composite material, Al-10%SiCp composites etc.

IV. EXISTING RESEARCH EFFORTS

Puertas et. al. [1] studied the influence of process parameters such as intensity, pulse-on-time and pulse-off-time for process performance criteria such as surface quality and dimensional precision. It has been shown that factorial design of experiments combined with techniques of regression may be applied for modeling the behavior of functions depending on several variables. Authors concluded that the factor having the most important influence on the surface roughness is the factor of intensity and also found that there is a strong interaction between the intensity (I) and the pulse on time factors being advisable to work with high intensity values and low pulse on time values.

Puri et. al. [2] employed mathematical modeling of white layer depth to correlate the dominant input parameters of the WEDM process, comprising of a rough cut followed by a trim cut. In the process, typical die steel (M2 hardened and annealed) was machined using brass wire as electrode. An experimental plan of rotatable central composite design in RSM consisting of input variable pulse on time during the rough cutting and pulse on time offset and cutting speed during trim cutting has been employed to carry out the experimental study and concluded that the white layer depth increases with increasing pulse on time during the first cut and decreases with increasing pulse on time during trim cutting. With increasing cutting speed in trim cutting, the white layer depth first reduces and then starts increasing.

T. A. El-Taweel [3] investigated the relationship of process parameters in EDM of CK-45 steel with novel tool electrode material such as Al-Cu-Si-TiC composite product using powder metallurgy technique. In this study, peak current, dielectric flushing pressure and pulse on time are considered as input process parameters and the process performances such as MRR and TWR were evaluated. The analysis was carried out with the help of response surface methodology. It was concluded that the peak current was found to be the most important factor effecting both the MRR and TWR while dielectric flushing pressure has little effect on both responses.
Al-Cu-Si-Tic electrodes were found to be more sensitive to peak current and pulse on time than conventional electrodes.

Sohani et. al. [4] 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 investigation revealed that the best tool shape for higher MRR and lower TWR is circular, followed by triangular, rectangular and square cross-sections. From the parametric analysis, it was also observed that the interaction effect of discharge current and pulse on time is highly significant on MRR and TWR, whereas the main factors such as pulse off time and tool area are statistically significant on MRR and TWR. The ANOVA was employed along with Fisher’s test (F test) at 95% confidence interval to verify the lack of fit and adequacy of developed model.

Mohd Amri Lajis et. al. [5] investigated the relationship of process parameters in EDM of Tungsten carbide was used as the workpiece material and graphite as electrode. In this study peak current, voltage, pulse on time and pulse off time are considered as input process parameters and the process performances such as metal removal rate (MRR), electrode wear (EWR) and surface roughness (SR). The Taguchi methodology has been used to formulate the experimental layout, to analyse the effect of each parameters on the machining characteristics, and to predict the optimal EDM parameters. It was concluded that, the peak current of EDM mainly affects the electrode wear and surface roughness and the pulse on time largely affects the metal removal rate.

S.H.Tomadi et. al. [6] Investigated the effect of process parameters like Pulse on time, Pulse off time. Supply Voltage, peak current on material removed rate (MRR) and electrode wear (EW). The Tungsten Carbide was used as the workpiece material and Copper Tungsten as electrode. The full factorial design of experiment was used to analyse the optimum condition of machining parameters. Author concluded that for surface roughness the most influential factor were voltage followed by pulse off time, peak current and in case of material removal rate, it was seen that the pulse on time factor was the most influential, followed by voltage, peak current and pulse off time.

K.D. Chattopadhyay et.al.[7] derived an empirical mathematical model for predication of output parameters has been developed using linear regression analysis by applying logarithmic data transformations of non-linear equation.

Experiment have been conducted with three machining parameters viz. peak current pulse on time and rotational speed of the electrode and to relate them with process responses viz. material removal rate (MRR), surface roughness (SR) and electrode wear ratio (EWR). Experiment was performed with copper- steel (EN-8) as workpiece and copper as electrode. Taguchi’s recommended signal-noise ratio formulae and ANOVA, has been conducted to identify the significant parameters and their degree of contribution in the process output. Authors concluded that the main influencing factors for metal removal rate and electrode wear ratio, in order of importance, include peak current, pulse on time and electrode rotation, respectively and for surface roughness main influencing factor were in order of importance, include peak current, electrode rotation and pulse on time, respectively.

K.M. Patel et.al.[8] derived quadratic mathematical model to represent the process behaviour of EDM. Experiments has been conducted with four process parameters viz. discharge current, pulse on time, duty cycle and gap voltage and to relate them with process response surface roughness (SR). Experiment was performed with AL2/SiCw/TiC ceramic composite as workpiece. Response surface method has been found efficient for prediction of process response for various combinations of factor setting. The significance of machining parameters selected has been established using analysis of variance. The surface roughness prediction model has been optimized using a trust region method. It was concluded that Pulse-on time is found to be the dominant parameter influencing surface roughness (SR) and it was also observed that an increase in discharge current increases the SR. The confirmation test showed that developed models can predict the SR accurately within95% confidence interval.

Asif Iqbal et. al.[9] established empirical relations regarding machining parameters and the responses in analyzing the machinability of the stainless steel AISI 304 using copper electrode. The machining factors used were voltage, rotational speed of electrode and feed rate over the responses MRR, EWR and SR. The response surface methodology was used to investigate the relationships and parametric interactions between the three control variables on the MRR, EWR and SR. the developed models show that the voltage and rotary motion of electrode are the most significant machining parameters influencing MRR, EWR and SR.
Saurav Datta et. al. [10] derived quadratic mathematical model to represent the process behavior of WEDM. Experiments has been conducted with six process parameters viz. discharge current, pulse on time, pulse frequency, wire speed, wire tension and dielectric flow rate and to relate them with process responses viz. MRR, SR and kerf (width of cut). Experiment was performed with D2 steel as workpiece and stratified wire (Zinc coated copper wire) as electrode. Response surface method has been found efficient for prediction of process response for various combinations of factor setting. Application of grey based Taguchi technique has been utilized to evaluate optimal parameter combination to achieve maximum MRR, minimum SR and minimum width of cut. Authors concluded that with increasing discharge current, pulse on time and wire speed, process response also increase while with increasing pulse frequency and wire tension, process responses decrease. Dielectric flow rate only influences the surface roughness and have a negative effect i.e., with increase in dielectric flow rate, surface roughness decreases.

Shailesh Dewangan et. al. [11] investigated the effect of process parameters like Pulse on time, Discharge current and Diameter of electrode on material removal rate (MRR), Tool wear rate (TWR) and over cut. The experiment used AISI P20 tool steel as workpiece and U-shaped copper tool as electrode with internal flushing system. The S/N ratios used for minimizing the TWR and maximizing the MRR and Taguchi method used for optimization the process parameters. It was concluded that pulse on time was the most influencing factor for MRR and then discharge current and the last one is the diameter of the tool. MRR increased with the discharge current and in case of the tool wear rate, the most influencing factor is pulse on time then discharge current and after that diameter of tool.

A. Majumder [12] derived quadratic mathematical model to represent the process behaviour of Die-Sinking Electrical Discharge Machining. Experiments has been conducted with three process parameters viz. discharge current, pulse on time and pulse off time and to relate them with process responses viz. material removal rate (MRR) and electrode wear (EW). Experiment was performed with mild steel as workpiece and copper as electrode sand finding that the effect of supply current on material removal rate is higher than the other machining parameters while in case of electrode wear (EW) the most influential factor was the intensity of the pulse-on time.

Anish et. al. [13] developed quadratic models for the machining rate, surface roughness and dimensional deviation to correlate the dominant machining parameters: pulse on time, pulse off time, peak current, spark gap voltage, wire feed & tension in wire EDM process for pure titanium. An experimental plan of the Box- Behnken based on RSM has been applied to perform the experimentation work and determined that the most significant parameters with respect to the response variables are found to be pulse on time, pulse off time, peak current & spark gap voltage and also conclude that the machining rate, surface roughness and dimensional deviations were fairly well fitted with the experimental results with 95% confidence level.

M. R. Shabgarg et.al [14] derived quadratic mathematical model to represent the process behaviour of Die-Sinking Electrical Discharge Machining. Experiments has been conducted with three process parameters viz. discharge current, pulse on time and voltage and to relate them with process responses viz. material removal rate (MRR) and stability factor (Sf). Experiment was performed with FW4 weld metal as workpiece and EC-16 graphite as electrode. It was concluded that material removal rate value first increase with the increase of pulse on time but for a specific pulse on time value it start to decrease and also observed that lower values of pulse-on time and pulse current, the occurrence of open-circuit pulses is the most considerable phenomenon. But in higher values of pulse current (roughing modes), the level of arc pulses extremely increases.

S. Gopalakannan et. al. [15] investigated the influence of process parameters and their interactions viz., pulse current, gap voltage, pulse on time and pulse off time on MRR, EWR and SR. Experiments were carried out to machine newly engineered metal matrix composite of aluminum 7075 reinforced with 10% of B4C particles using copper as electrode. Response Surface Methodology had been employed to develop mathematical model and to establish empirical relationships between process parameters and process responses. Analysis of variance was carried out to validate the experimental results. It was concluded that the two main significant factors that affects the MRR are pulse current and pulse on time. The MRR first increases and then decreases with increasing pulse on time. The surface roughness increases with increase in pulse current and pulse on time & surface roughness decreases upto 50 volt and then increases with further increase in voltage.
Raj Mohan et al. [16] investigated the influence of process parameters and their interactions viz., voltage, pulse on time, current and pulse off time on the material removal rate (MRR) in stainless steel (304) as workpiece. Signal to noise ratio (S/N) and analysis of variance (ANOVA) was used to analyze the effect of the parameters on MRR and Taguchi method used to find the optimum cutting parameters. It was concluded that the two main significant factors that affects the MRR are pulse current and pulse on time.

Herpreet Singh et al. [17] studied the influence of operating parameters like pulse-on-time and pulse-off-time for responses such as Metal removal rate (MRR) and Tool Wear Ratio (TWR) on the EDM using steel as workpiece and cryogenic and non-cryogenic electrode of copper material. The cryogenic treatment is used for increasing the material removal rate and lowering the tool wear rate. It was found that with increase in pulse on time tool wear rate is decreased in both electrode cryogenic treated and non-cryogenic copper electrode. Tool wear rate is increased with increase in pulse off time. Material removal rate is decreased with increased in pulse on time from 50μs to 100μs and Material removal rate is increased with increased in pulse off time from 15μs to 20μs.

S V Subrahmanyam et al. [18] derived non-liner mathematical model to represent the process behavior of WEDM. Experiments has been conducted with eight process parameters viz. discharge current, pulse on time, pulse off time spark voltage, wire tension, wire feed, servo feed and flushing pressure of dielectric fluid to relate them with process responses viz. material removal rate (MRR) and surface roughness (SR). Experiment was performed with H13 Hot Die tool steel as workpiece and stratified wire (Zinc coated copper wire) as electrode. The grey based Taguchi technique has been utilized to evaluate optimal parameter combination to achieve maximum MRR, minimum roughness value; with selected experimental domain. It was concluded that the Grey-Taguchi Method, is most ideal and suitable for the parametric optimization of the Wire-Cut EDM process, when using the multiple performance characteristics such as MRR and SR for machining the H13 or for the matter for any other material.

Prajapati et al. [19] investigated the effect of process parameters like Pulse ON time, Pulse OFF time, Voltage, Wire feed & Wire Tension on MRR, SR, Kerf. The AISI A2 tool steel was used as the workpiece material in form of square bar. Response surface methodology was used to analyze the data obtained from the experiment for optimization and performance.

Authors concluded that for cutting rate and surface roughness, the pulse ON and pulse OFF time is most significant. The spark gap voltage is significant for kerf. The normal probability distribution for all measurement indicates high confidence.

Nikalje et al. [20] studied the influence of process parameters such as discharge current, pulse-on-time and pulse-off-time for process performance criteria such as MRR, Tool Wear Ratio (TWR), Relative Wear Ratio (RWR) and surface roughness. The MDN 300 steel was used as workpiece material and copper as electrode. The Taguchi method was employed for optimization. It was found that the optimal levels of the factors for SR and TWR are same but differs from the optimum levels of the factors for MRR and RWR. From ANOVA, discharge current is more significant than pulse on time for MRR and TWR; whereas pulse on time is more significant than discharge current for RWR and SR. on the other hand, pulse off time is less significant for all performance characteristics considered.

C. D. Shah et al. [21] studied the optimization of the process parameters during machining of Inconnel-600 and molybdenum wire as electrode in WEDM by using response surface methodology (RSM). Four input process parameters viz. peak current, pulse on time, pulse off time and wire feed rate were considered to study the process performance in terms of MRR. In this study, the parametric optimization method using Taguchi’s robust design was proposed for WEDM. The analysis of variance (ANOVA) was carried out to study the effect of process parameters on process performance. It was found that pulse on time, pulse off time, peak current were the most effective parameters for MRR.

Chikalthankar et al. [22] studied the influence of operating parameters like current, voltage, pulse-on-time and pulse-off-time for responses such as MRR and surface roughness on the EDM of WPS DIN 1.2379/AISI D2 tool steel using the copper electrode material. The Taguchi method Design of Experiment is conducted with L9 orthogonal array and Multi-objective optimization is carried out with the help of Response surface methodology to optimize both the responses at the same time and it was found that current is more influential parameter affecting the MRR and surface roughness.

Kumar et al. [23] optimized the parameters of WEDM process by considering the effect of input parameters viz. pulse on time, pulse off time, wire speed and wire feed on process responses viz. MRR and SR while machining Al-sic (20%) plate using molybdenum wire.
The RSM quadratic mathematical model has been utilized to represent the process responses as a function of process parameters. The Taguchi method has been used for minimizing the surface roughness. It was found that factors like pulse on time, pulse off time, wire speed and wire feed play a significant role for material removal rate and surface roughness. Geetha et. al. [24] considered four process variables such as pulse on time, pulse off time, wire tension and water pressure and used stainless steel 304 material as workpiece. Authors used Response surface methodology (RSM) to develop the quantitative relationships between the input and the output response for the experiment data collected as per the design of experiment. Also the effects of the input process parameters over the MRR and surface roughness were studied. It was showed that the second-order model can explain the variation in the SR and the MRR up to the extent of 89% and 97% respectively.

Neeraj Sharma et. al. [25] investigated the effect of process parameters such as pulse on time, pulse off time, peak current, servo voltage and wire tension on process responses such as MRR and SR while machining HSLA using brass wire as electrode. Response surface methodology was used to formulate mathematical model and to optimize the process parameter for MRR and SR. Authors concluded that the most significant factors for MRR are pulse on time, pulse off time and servo voltage & pulse on time is a significant factor for surface roughness calculation. Singaram Lakshmanan et. al. [26] demonstrated the optimization process of material removal rate (MRR) of EDM by response surface methodology (RSM). The workpiece material was EN31 tool steel and the electrode material was copper. The pulse on time, pulse off time, pulse current and voltage were the control parameters. The process had been successfully modeled using response surface methodology and model adequacy checking was also carried out using Minitab software. The second-order response models had been validated with analysis of variance & the optimum machining conditions to produce a best possible response within the experimental constraints were estimated.

Sanjay Kumar et. al. [27] presented a hybrid optimization approach for the determination of the optimal process parameters which maximize the material removal rate and minimize surface roughness & tool wear rate.

The input parameters of EDM considered for this analysis were pulse current, pulse on time & pulse off time. The influences of these parameters had been optimized by multi response analysis. The effects of the parameters on the responses were evaluated by response surface methodology which is based on optimization results. On the basis of optimization results, it had been found that pulse current of 5A, a pulse on time of 60µs & pulse off time of 45µs were the best combination of this analysis.

Manabhanjan Sahoo et. al. [28] studied the influence of process parameters such as discharge current, pulse-on-time and duty cycle for process performance criteria such as metal removal rate (MRR) and electrode wear rate (EWR). Experiments are conducted on tungsten carbide with copper electrode in a die sinking EDM. Response Surface Methodology had been employed to develop mathematical model and to establish empirical relationships between process parameters and process responses. It was found that the peak current was found to be the most important factor effecting both the MRR and EWR. It had been found that the Maximum MRR was achieved at 10 A discharges current, 50µs pulse on time and 8 duty cycle and minimum EWR was achieved at 6 A discharge current, 10µs pulse on time and 8 duty cycle.

Md. Khaja et. al. [29] considered the effects of various machining parameters on machined surface roughness. In the process, typical die steel (K 100 grade) was machined using brass wire as electrode. Pulse on time, pulse off time, wire feed rate, wire tension, spark gap set voltage and peak current were the machining parameters chosen to conduct the experiment. After analyzing the effect of each relevant factor on surface roughness, appropriate values of all parameters are chosen and a fine surface of roughness equals to 0.22 µm is achieved. It was concluded that pulse on time and pulse off time were significant variables to the surface roughness. It was noticed that excellent machined surface quality could be obtained by setting machining parameters at a low pulse current and short pulse on time. But this combination will unfortunately produce low material removal rate and cause high machining time.

The specific analysis performed in the different areas as discussed by this review paper.
### TABLE I
The specific analysis performed in the different areas as discussed by this review paper

<table>
<thead>
<tr>
<th>Name of Researchers</th>
<th>Year</th>
<th>Contribution</th>
<th>Workpiece material</th>
<th>Electrode Material</th>
<th>Parameters</th>
<th>Machining</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puertas et. al.</td>
<td>2003</td>
<td>Investigated the machining parameters optimization of electrical discharge machining</td>
<td>-</td>
<td>-</td>
<td>Pulse on time, Current intensity, Pulse off time</td>
<td>Surface Quality, Dimensional Precision</td>
<td></td>
</tr>
<tr>
<td>Puri et. al.</td>
<td>2004</td>
<td>Investigation of White Layer Depth in a Wire-Cut EDM Process Through Response Surface Methodology</td>
<td>Die steel</td>
<td>Brass</td>
<td>Pulse on time</td>
<td>Cutting speed, White layer depth</td>
<td></td>
</tr>
<tr>
<td>T.A.El-Taweel</td>
<td>2008</td>
<td>Investigated the multi-response Optimization of EDM with Al-Cu-Si-TiC P/M Composite Electrode</td>
<td>C’k 45 Steel</td>
<td>Al-Cu-Si-TiC P/M Composite</td>
<td>Peak- Current, Dieelectrical flushing pressure, Pulse on time</td>
<td>MRR, TWR</td>
<td></td>
</tr>
<tr>
<td>Sohani et. al.</td>
<td>2009</td>
<td>Investigations into the Effect of Tool Shapes with Size Factor consideration in Sink Electrical Discharge Machining (EDM) Process</td>
<td>-</td>
<td>-</td>
<td>Discharge current, Pulse on time, Pulse off time, Tool area</td>
<td>MRR, TWR</td>
<td></td>
</tr>
<tr>
<td>Mohd. Amri Lajis et. al.</td>
<td>2009</td>
<td>The Implementation of Taguchi Method on EDM Process of Tungsten Carbide</td>
<td>Tungsten carbide</td>
<td>Graphite</td>
<td>Peak current, Voltage, Pulse on time, Pulse off time</td>
<td>MRR, EWR, SR</td>
<td></td>
</tr>
<tr>
<td>S.H.Tomadi et. al.</td>
<td>2009</td>
<td>Analysis of the Influence of EDM Parameters on Surface Quality, Material Removal Rate and Electrode Wear of Tungsten Carbide</td>
<td>Tungsten carbide</td>
<td>Copper tungsten</td>
<td>Pulse on time, Pulse off time, Supply voltage, Peak current</td>
<td>MRR, EW</td>
<td></td>
</tr>
<tr>
<td>K.D.Chattopadhyay et. al.</td>
<td>2009</td>
<td>Development of empirical model for different process parameters during rotary electrical discharge machining of copper–steel (EN-8) system</td>
<td>Copper steel (EN-8)</td>
<td>Copper</td>
<td>Peak current, Pulse on time, Rotational speed</td>
<td>MRR, SR, EWR</td>
<td></td>
</tr>
<tr>
<td>K.M.Patel et. al.</td>
<td>2009</td>
<td>Investigated the determination of an Optimum Parametric Combination Using a Surface Roughness Prediction Model for EDM of Al₂O₃/SiC₆/TiC Ceramic Composite</td>
<td>Al₂O₃/SiC₆/TiC Ceramic Composite</td>
<td>-</td>
<td>Dischagre current, Pulse on time, Duty cycle, Gap voltage</td>
<td>SR</td>
<td></td>
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<tr>
<td>Asif Iqbal et. al.</td>
<td>2010</td>
<td>Investigated modeling and analysis of MRR, EWR and Surface Roughness in EDM Milling through RSM</td>
<td>Stainless steel ( AISI 304)</td>
<td>Copper</td>
<td>Voltage, Rotational speed, Feed rate</td>
<td>MRR, EWR, SR</td>
<td></td>
</tr>
<tr>
<td>Author et al.</td>
<td>Year</td>
<td>Methodology</td>
<td>Material</td>
<td>Wire Type</td>
<td>Parameters</td>
<td>Objective(s)</td>
<td></td>
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<tr>
<td>Saurav Datta et al.</td>
<td>2010</td>
<td>Modeling, Simulation and Parametric Optimization of Wire EDM Process using Response Surface Methodology coupled with Grey-Taguchi Technique</td>
<td>D2 steel</td>
<td>Stratified wire</td>
<td>Discharge current, Pulse on time, Pulse frequency, Wire speed, Wire tension, Dielectric flow rate</td>
<td>MRR, SR, Kerf</td>
<td></td>
</tr>
<tr>
<td>Shaileshe et al.</td>
<td>2011</td>
<td>Experiment Investigation of Machining Parameters for EDM Using U- shaped Electrode Of AISI P20 Tool Steel</td>
<td>AISI P20 Tool Steel</td>
<td>Copper</td>
<td>Pulse on time, Discharge current, Diameter of electrode</td>
<td>MRR, TWR</td>
<td></td>
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<tr>
<td>A. Manjuder</td>
<td>2012</td>
<td>Study of the Effect of Machining Parameters on Material Removal Rate and Electrode Wear during Electric Discharge Machining of Mild Steel</td>
<td>Mild Steel</td>
<td>Copper</td>
<td>Supply Current, Pulse on time, Pulse off time</td>
<td>MRR, EW</td>
<td></td>
</tr>
<tr>
<td>Anish et al.</td>
<td>2012</td>
<td>Prediction of Surface Roughness in Wire Electric Discharge Machining (WEDM) Process based on Response Surface Methodology</td>
<td>Pure Titanium</td>
<td>Copper</td>
<td>Pulse on time, Pulse off time, Peak current, Spark gap voltage, Wire feed, Wire tension</td>
<td>SR</td>
<td></td>
</tr>
<tr>
<td>M.R. Shabgarg et al.</td>
<td>2012</td>
<td>Mathematical Analysis of Electrical Discharge Machining on FW4 Weld Metal</td>
<td>FW4 weld metal</td>
<td>EC 16 Graphite</td>
<td>Discharge Current, Pulse on time, Voltage</td>
<td>MRR, Stability factor ($S_f$)</td>
<td></td>
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<tr>
<td>S. Gopalakannan et al.</td>
<td>2012</td>
<td>Modeling and Optimization of EDM Process Parameters on Machining of Al 7075-B_4C MMC using RSM</td>
<td>Al 7075-B_4C MMC</td>
<td>Copper</td>
<td>Pulse current, Gap voltage, Pulse on time, Pulse off time</td>
<td>MRR, EWR, SR</td>
<td></td>
</tr>
<tr>
<td>Raj Mohan et al.</td>
<td>2012</td>
<td>Optimization of Machining Parameters in Electrical Discharge Machining (EDM) of (304) stainless steel</td>
<td>Stainless Steel (304)</td>
<td>-</td>
<td>Pulse off time, Pulse on time, Voltage</td>
<td>MRR</td>
<td></td>
</tr>
<tr>
<td>Herpreet Singh et al.</td>
<td>2013</td>
<td>Effect of Pulse on / Pulse off on Machining of Steel Using Cryogenic Treated Copper Electrode</td>
<td>Steel</td>
<td>Copper</td>
<td>Pulse on time, Pulse off time</td>
<td>MRR, TWR</td>
<td></td>
</tr>
<tr>
<td>S V Subrahmanyam et al.</td>
<td>2013</td>
<td>Evaluation of Optimal Parameters for machining with Wire cut EDM Using Grey-Taguchi Method</td>
<td>H13 Hot Die tool steel</td>
<td>Stratified wire</td>
<td>Discharge current, Pulse on time, Pulse off time, Spark voltage, Wire feed, Wire tension, servo feed, flushing pressure</td>
<td>MRR, SR</td>
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<td>Authors</td>
<td>Year</td>
<td>Title</td>
<td>Material</td>
<td>Parameters</td>
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<tr>
<td>Prajapati et. al.</td>
<td>2013</td>
<td>Effect of Process Parameters on Performance Measures of Wire EDM for AISI A2 Tool Steel</td>
<td>AISI A2 Tool Steel</td>
<td>Pulse on time, Pulse off time, Voltage, Wire feed, Wire tension</td>
<td>MRR, SR, Kerf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nikalje et. al.</td>
<td>2013</td>
<td>Influence of Parameters and Optimization of EDM Performance Measures on MDN 300 Steel using Taguchi Method</td>
<td>MDN 300 Steel Copper</td>
<td>Discharge current, Pulse on time, Pulse off time</td>
<td>MRR, TWR, RWR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. D. Shah et. al.</td>
<td>2013</td>
<td>Optimization of Process Parameter of Wire Electrical Discharge Machine by Response Surface Methodology on Inconel-600</td>
<td>Inconel-600 Molybdenum</td>
<td>Peak current, Pulse on time, Pulse off time, Wire feed</td>
<td>MRR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chikalthankar et. al.</td>
<td>2013</td>
<td>Experimental Investigations of EDM Parameters</td>
<td>WPS DIN 1.2379/AISI D2 tool Steel Copper</td>
<td>Current, Voltage, Pulse on time, Pulse off time</td>
<td>MRR, SR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kumar et. al.</td>
<td>2013</td>
<td>Modeling and Optimization of Wire EDM Process</td>
<td>Machining Al-Mnic (20%) Molybdenum</td>
<td>Pulse on time, Pulse off time, Wire speed, Wire feed</td>
<td>MRR, SR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geetha et. al.</td>
<td>2013</td>
<td>Modeling and Analysis of Performance Characteristics of Wire EDM of SS304</td>
<td>Stainless steel 304 -</td>
<td>Pulse on time, Pulse off time, Wire tension, Water pressure</td>
<td>MRR, SR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neeraj Sharma et. al.</td>
<td>2013</td>
<td>Multi Quality Characteristics of WEDM Process Parameters with RSM</td>
<td>HSLA Brass</td>
<td>Pulse on time, Pulse off time, Peak current, Servo voltage, Wire tension</td>
<td>MRR, SR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singaram Lakshmanan et. al.</td>
<td>2013</td>
<td>Optimization of EDM Parameters using Response Surface Methodology for EN31 Tool Steel Machining EDM Process</td>
<td>EN31 tool steel Copper</td>
<td>Pulse on time, Pulse off time, Pulse current, voltage</td>
<td>MRR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanjay Kumar et. al.</td>
<td>2013</td>
<td>Optimization of EDM Parameters using Integrated Approach of RSM, GRA and Entropy Method</td>
<td>- -</td>
<td>Peak current, Pulse on time, Pulse off time</td>
<td>MRR, SR ,TWR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manabhanjan Sahoo et. al.</td>
<td>2013</td>
<td>Experimental Investigation of Machining of Tungsten carbide by EDM and Its Mathematical Expression</td>
<td>Tungsten carbide Copper</td>
<td>Discharge current, Pulse on time, Duty cycle</td>
<td>MRR, EWR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Md. Khaja et. al.</td>
<td>2013</td>
<td>Effects of Machining Parameters on Surface finish over Hardened Die Steel working on Wire-EDM Machine.</td>
<td>Die Steel (K100 grade) Brass</td>
<td>Pulse on time, Pulse off time, Wire feed, Wire tension, Spark gap, Voltage, Peak current</td>
<td>SR</td>
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V. CONCLUSION

The analysis in this area over the past two decades reveals that EDM performance is generally evaluated on the basis of TWR, RWR and SR. The performance is affected by discharge current, pulse on time, pulse off time, arc gap, duty cycle, wire feed, wire tension, servo voltage, rotational speed and flushing pressure. The review paper evaluates the areas and subareas where optimization techniques have been deployed. It works on identifying parameters for optimization and also suitable techniques for EDM mechanism.

REFERENCES


