TO STUDY THE MULTI-OBJECTIVE OPTIMIZATION OF EDM USING GENETIC ALGORITHM

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ABSTRACT

In the manufacturing industry, the production and quality of a product is very important, especially when it involves the big industries EDM. A machine such as EDM (electro discharge machine) used to produce a product that require an accurate product quality. EDM is one of the most accurate manufacturing processes for creating geometric shapes whether complex or simple in parts and assemblies. Development of EDM process has resulted in significant improvements in operating techniques, productivity and accuracy, which the result of this machining development has helped variability in EDM process. The main purpose of this study is to optimize the parameters used in EDM machining such as non-electrical parameter, electrical parameters, the characteristics of the machining, work piece and the variable parameters that will affect the actual machining performances such as material removal rate (MRR), electrode wear ratio (EWR), and surface roughness (SR). In the process of the study, the second- order mathematical model has been create as a fitness function using MATLAB software to generate multi-objective optimization responses using Genetic Algorithms, peak current, pulse-on time, pulse-off time and servo voltage are act as input of parameter setting. Based on the responses from EDM machining process which has been conducted showed the parameter is effect the level of machining performances in order to get the optimum value.

ABSTRAK

Dalam industri pembuatan, penghasilan sesuatu produk amat penting terutamanya apabila ianya melibatkan industri besar seperti pemotoran. Mesin seperti EDM (pemesinan nyahcas electrik) digunakan untuk menghasilkan produk seperti injap yang memerlukan pengukuran yang jitu bagi mengelakkan sebarang kesilapan semasa proses pemasangannya. EDM adalah satu proses pembuatan yang paling tepat untuk mewujudkan bentuk dan geometri yang kompleks atau mudah dalam bahagian dan pemasangan. Pembangunan dalam proses EDM telah menghasilkan perbaikan yang penting dalam operasi teknik, produktiviti dan ketepatan, manakala hasil daripada pembagunan ini telah membantu kepelbagaian dalam proses EDM. Dalam projek ini, ianya merangkumi beberapa aspek penting untuk menghasilkan satu rekabentuk injap dalam sistem enjin yang melibatkan rekabentuk peralatannya menggunakan mesin larik dan fabrikasinya menggunakan mesin EDM. Tujuan utama kajian ini dijalankan adalah untuk mengoptimumkan parameter yang digunakan dalam pemesinan EDM seperti parameter tanpa elektrik, parameter dengan elektrik, ciri-ciri pemesinan, benda kerja dan parameter bolehubah yang memberi kesan terhadap prestasi sebenar pemesinan seperti kadar pembuangan bahan (MRR), nisbah kehausan elektrod (EWR), dan kekasaran permukaan (SR). Dalam proses kajian, fungsi kuadratik telah digunakan sebagai fungsi tetap untuk melaksanakn perisian MATLAB untuk menjana mendapatkan pengoptimuman fungsi pelbagai objektif menggunakan ‘Genetic Algorithms’ yang melibatkan puncak semasa, nadi masa dan voltan servo sebagai input setting parameter. Berdasrkan tindak balas daripada proses pemesinan EDM yang dijalankan menunjukkan parameter yang digunakan mempengaruhi tahap prestasi pemesinan untuk mendapatkan nilai yang optimum.

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LIST OF SYMBOLS

β_0	Constant
β_i, β_{ij}, β_{ii}	Regression coefficient
ε	Experimental error
f	Function
f_{max}	Maximum value of function
g	Optimum pulse time factor
I_p	Peak current
R_a	Roughness average
S_v	Servo voltage
T_{on}	Pulse-on time
T_{off}	Pulse-off time
Y	Response

LIST OF ABBREVIATIONS

ANN	Artificial neural network
Cu	Copper
DC	Direct control current
DM	Decision maker
EA	Evalutionary Algorithm
EDM	Electrical discharge machining
EW	Electrode wear
EWR	Electrode wear rate
GA	Genetic Algorithm
MATLAB	Matrix Laborotary
MOGA	Multi-objective Genetic Algorithm
MO	Multi-objective
MOP	Multi-objective Pareto
MRR	Material removal rate
MR	Machining performance
RSM	Response surface methodology
SR	Surface roughness
VMCPM	Variable mass cylindrical plasma model

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Electrical Discharge Machining (EDM) was first introduced in the 1940's as a crude device used to cut broken machining tools from expensive in-process parts. Since that time EDM has become a sophisticated and indispensable technology, revolutionizing the tool, die, and mould making industries, and making significant inroads into the production of highly accurate, intricate and difficult to machine production parts. EDM or electro discharge machine is an electro-thermal non-traditional machining where performs as one of the most accurate manufacturing process.

EDM is mainly function to machine or cutting the difficult material which have a strong bounded between of each molecule and perform in high strength temperature resistant alloys (Kharagpur, 2011). Figure 1.1 shows, electrical is used as power generator to create the discharge energy between a tool which called as electrode and the part being machined in order to produce electrical spark. In the EDM process, the workpiece must be a conductive electricity material which is submerges into the dielectric fluid for better erosion. While applying the EDM process the material is removing due to thermal energy of the electric spark and this process will produce the desired shape. EDM is one of the alternative machining processes that can be used successfully where the process can perform almost every conductive material, regardless of its stiffness. Although these methods cannot reach the dimensional magnitudes of photo-fabrication techniques, such magnitudes are not required in many cases.

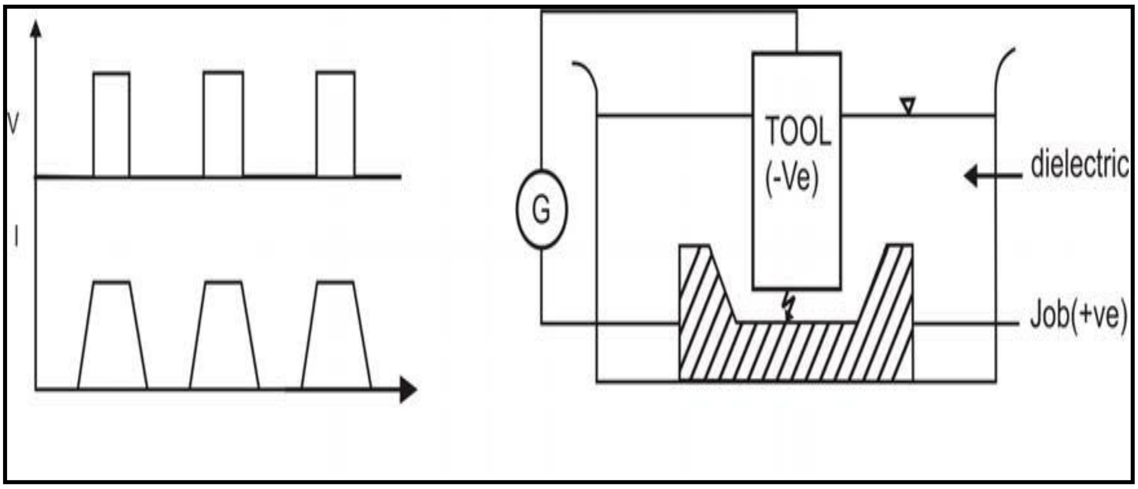

Figure 1.1: Schematic representation of the basic working principle of EDM process

Source: Kharagpur (2011)

In order to optimize the machining performance, the number of material removal rate (MRR) has to maximize due to the machine parameters setting. When the electric power is apply over the EDM machine, the thermal energy will produces the spark leads to intense the workpiece and will causing melting and vaporized of the workpiece material. Due to high temperature of the spark, the electrode melted and vaporized which know as tool wear. Tool wear process is similar to the material removal mechanism. A part of that, the response from the machining process is effect of electrode wear rate (EWR) and surface roughness (SR) are desirable to consider to get the optimum value of the design workpiece. At present EDM parameter selection is one experience process in the industry. According to the analysis the effective parameters on surface roughness, material removal rate and electrode wear in EDM. Based on machining performance, each parameter evaluate the effect of current, pulse on-time and pulse off-time on surface roughness, material removal rate and electrode wear on finishing stage. In addition, it present proper second degree regression models for predicting surface roughness, material removal rate and electrode wear. The variables parameters are have great effects to the machining performances results especially to the material removal rate (MRR), electrode wear rate and surface quality.

1.2 PROJECT OVERVIEW

Electrical discharge machine (EDM) is commonly used in tool, die and mould making industries for machining heat-treated tool steel materials. The heat treated tool steels material falls in the difficult-to-cut material group when using conventional machining process. The high rate of electrode wear is one of the main problems in electrical discharge machine (EDM). The wear rate defined as the volume of metal lost from the tool divided by the volume of metal removed from the work material varies with the tool and work materials used. If the rate of tool wear is high means that the material is easy to wear and not good for machining performance.

The significant of this study is to promote the consideration of parameter selection in electrical discharge machine (EDM) machine for advance machining in the manufacturing industries. This is because every parameter materials have their own characteristic that lead to different result due to its properties. Electrical discharge machine (EDM) has been analyzed since several years in order to improve the material removal rate, electrode wear rate and surface roughness which are the most critical aspects of the process. In the machining of electrical discharge machine (EDM), there are a few characteristics which influence the machining process. Most important influence is polarity, peak current, pulse duration, servo voltage the. This machining parameter should be taken into account when good machining performance is needed.
The case studies of this project are to maximize the material removal rate (MRR) and surface roughness (SR) and to minimize electrode wear rate (EWR) from different ranges of parameters. This would lead to the better process and product finishing.

1.3 PROBLEM STATEMENT

The important goal in the modern industries is to manufacture the products with lower cost and high quality in short span of time. There are two main practical problems that engineers face in a manufacturing process. The first is to select the appropriate parameters and predict the ranges of the input parameter that will yield the desired product quality (meet technical specifications) that avoid such circumstances. The selection have the selection must be construed in accordance with the most significance of EDM process in order to deducted the manufacturing cost. The second problem is to consider the manufacturing system performance using the available resources. As consideration in problem one, some of the parameter settings that given by manufactures are only applicable to the common steel grades. Due to the circumstances the selection of electrical parameter is one of the important things that need to be emphasized to ensure that production processes are implemented properly when other materials are used. However, EDM manufactures only supply the parameters for limited amount of the material combination (Dewangan, 2010).

As consider of the two problems in manufacturing industries, optimization is exact solution to improve the quality of production. Material removal rate (MRR), electrode wear rate (EWR), surface roughness (SR) are the machines characteristic that need to be considered to determine and evaluate the quality of production. Commonly in prepared the set of input variables still not achieve the exact value of material removal rate, electrode ear ratio and surface roughness because of the machine itself or how operators handle the job (Marafona and Wykes, 2000). Engineer play as a part in this situation where they need to refer some methodology from the right sources to predict the EDM responses based on the combination between input parameter, machine accuracy and the stability on the material behaviour. Achieving the desired quality of the production is the great importance for the functional behaviour of a part. Mainly, the design consideration of machine characteristic is a measure of the quality of a product and a factor that greatly influences manufacturing cost, waste, time and vice versa. In this research, the technique to predict the correlate process parameter and EDM performance characteristic in EDM on Ti-6A-14V has been made to improve the production in EDM industries.

1.4 RESEARCH OBJECTIVE

The intention of this research is to simultaneous optimize MRR, EWR and SR. The specific objectives are to:

i. Investigate the effect of EDM machining parameters on the performance characteristic in term of material removal rate (MRR), electrode wear rate (EWR) and surface roughness.

ii. Develop function from second-order mathematical model equation and using multi-objective Genetic Algorithm method.

iii. Obtain the optimal response parameter to the higher material removal rate (MRR), the lowest electrode wear ratio (EWR) and superior surface roughness at finishing line (SR).

1.5 SCOPE OF STUDY

The analysis on EDM performance characteristic is carried out by the Genetic Algorithm method as a solver to find the significance effect by comparing between maximize value of material removal rate, minimize value of electrode wear rate and surface roughness. In the present research, the parameter is selected by the evaluations of the most effectiveness in EDM process. The ranges of the parameter are selected as peak current (1-29 A), pulse-on time (10-350 μS), pulse-off time (60-300 μS), servo voltage (75-115 V) and the polarity of the electrode is retained as positive. In order to investigate the performance characteristics, material removal rate, electrode wear ratio and surface roughness selected as output. In the present study, to obtain the difference between each performance characteristic, Genetic Algorithm is selected as a solver technique to analyze the slope from the data provided. The number of result is not the same for each analysis because it depending on how many reading can be taken during iteration running using GA solver.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide a review in summary and explanation from the complete research and the knowledge from the current research of the electrical discharge machining process parameter, performance characteristics, and the method related to the process parameters and performance characteristics on the EDM process of titanium alloy, Ti-6A-14V. The strength of the literature review is depended from the sources of the books and journal articles which are provide the relevant information to the research project. As referring to the EDM process, there are no offerings in any technologies to the setting of the machining parameters to achieve the desired machining performance, and because of that the research in related potentials are highly needed. The reviews produced in this chapter are accordance with the requirements of the research and proper format to ensure it coincide with the work performed.

2.2 ELECTRICAL DISCHARGE MACHINING

2.2.1 History

Electrical discharge machining (EDM) is a non-traditional manufacturing process based on removing material from a part by means of a series of repeated electrical discharges (created by electric pulse generators at short intervals) between a tool, called electrode, and the part being machined in the presence of a dielectric fluid (Poco Graphite, 1994). EDM is a well-established machining especially in the option for manufacturing geometrically complex or hard material parts that are extremely difficult to machine by conventional machining processes.

Back to the year 1770's, when the English physicist Joseph Priestly has discover in his research that the erosive effect of the various metal can produce electrical discharges. Based on Priestley's earlier research, during a separate study to eliminate the erosive effect on electrical contacts, the Soviet researchers and Lazarenko had the idea of exploiting the destructive effects of an electrical discharge and develop a controlled process for machining of metals. Taking the same idea, in year 1943 the Russian scientists taken the full advantage of the erosive effects to introduce a spark machining process which a succession of sparks (electrical discharges) took place between two electrical conductors immersed in a dielectric fluid (Ross, 1988).

The development of spark machining process is continue in year 1952, when the manufacturer Charmilles created the first machine using the fundamental of erosive effect. Have interest in spark erosion machining, Charmilles use the advantages of the discharges generator affect to construct of EDM machines and presented for the first time at the European Machine Tool Exhibition in Milan in 1955.

2.2.2 Basic Principles

EDM is accomplished with a system comprising two major components which is machine tool and power supply. As machining operation system, EDM machine tool act as holder a shaped of electrode and feed into the workpiece to produce a high frequency series of electrical spark discharges. The sparks are generated by a pulse generator, between the tool electrode and the work material, submerged in a liquid dielectric, leading to metal removal from the work material by thermal erosion or vaporization. The EDM phenomenon, as it is understood, can be divided into three stages namely application of adequate electrical energy, dielectric breakdown, sparking, and expulsions (erosion) of work material. The spark erosion of the work material makes use of electrical energy, converting them into thermal energy through a series of repetitive electrical discharges between the tool electrode and the work material electrode.

The thermal energy generates a channel of plasma between the two electrodes have produce a high temperature range is about 8000 to 12000 ℃ and allow to achieve until 20,000 ℃ (Mahardika and Mitsui, 2007). In part of EDM operating time, DC supply produce the pulsed ~20,000-30,000 Hz which have ability to breaking down of plasma channel while the power is terminated. Refer to this condition, the reduction in the temperature happened and together with it the circulating dielectric fluid flush away from the molten work material in EDM machined surface in form of microscopic debris. Melting and vaporization of the work material dominates the material removal process in EDM, leaving tiny craters on the surface of the work material.

2.2.3 Flushing

One of the common in EDM machining process is flushing. Flushing defined as the correct circulation of dielectric fluid between electrodes and workpiece. As a part to get the ideal machining performances, flushing is suitable conditions to obtain the highest machining efficiency. Nevertheless, is importance to develop the understanding of the correct application of flushing in EDM process in order to handling the phenomenon that occurs in machining gap when flushing is absent (Pandey and Shah, 1980). As a prevention of the flushing operating, the dielectric needs to be free from the eroded particles and carbon residue to avoid the dielectric cracking when a high strength is subjected over it. With successive discharges the dielectric gets contaminated, reducing its insulation, and hence, discharge can be taken easily but opposite of the result could might be happen if the density of the particles becomes too high at certain points within the gap, 'bridges' are formed which lead to abnormal discharges and damage the tool as well as the work electrode. This build-up of the wear debris is eliminated by flushing. Furthermore, flushing is EDM operating processes that have ability to control the electrical parameter in the dielectric which influence the optimum value of machining performances. Flushing is divided into four main components which is injection flushing, suction flushing, side flushing and flushing by dielectric pumping.

Injection flushing is an external flushing method which also called as jet flushing. Jet flushing is applied with the nozzles fixed at positions which are decided on the basis of the operator's experience. A hole is provided in the workpiece or tool for this purpose (Pandey and Shah, 1980). Upon to the suction flushing characteristic have a different method compared to the injection flushing where use a vacuum to draw the contaminated dielectric away from the gap as opposed to forcing it out with pressure. Described of the vacuum method, the fluid is sucked trough the workpiece or the tool electrode. Suction has the advantage to control the taper effects due to sparking via particles along the sides of the electrode compared to injection flushing. This situation are improved from the suction operation which the suction flushing is flow from the tool rather than through the workpiece that proved to be more efficient.

Continue with the side flushing, the operation is employed when flushing holes cannot be drilled either in the workpiece or the tool. However, side flushing cannot handle a process imposed upon it continuously in case when the entire working area needs to be evenly flushed, the especial precaution has to be taken likely the pumping of dielectric. Flushing by dielectric pumping is obtained by using the electrode pulsation movement. When the electrode is raised, the gap increases, resulting in clean dielectric being sucked into mix contaminated fluid, and as the electrode are lowered, the particles are flushed out. This method has been found particularly suitable in deep hole drilling (Pandey and Shah, 1980).

2.3 EDM PERFORMANCE CHARACTERISTICS

2.3.1 Material Removal Rate

The first serious attempt of providing a physical explanation of the material removal during electric discharge machining is that of Dijck (1972). According to the research which presented in physic mathematical analysis of the process over a thermal model together with a computational simulation, the first attempt explained that the phenomena between the electrodes during electric discharge machining is one of the performances characteristic where improve the value of production. On the late eighties and early nineties, the new models were developed to explain the phenomena that occur during electric discharge machining in terms of heat transfer theories. In the first paper, a simple cathode erosion model for the process was presented (Dibitonto and Barrufet, 1989). Based on this research the heat-source model differed from Dijack (1972) where the conduction models in the way that it accepts power rather than temperature as the boundary condition at the plasma or cathode interface.

Optimum pulse times were predicted to within an average of 16% over a two-decade range after the model is tuned to a single experimental point. In this model, a constant fraction of the total power supplied to the gap was transferred to the cathode over a wide range of currents. A universal, dimensionless model was then presented which identifies the key parameters of optimum pulse time factor (g) and erodibility (j) in terms of the thermo physical properties of the cathode material. Compton's original energy balance for gas discharges was amended for EDM conditions was found that the high density of the liquid dielectric causes plasmas of higher energy intensity and pressure than those for gas discharges. Besides, the differences of macroscopic dielectric properties affect the microscopic mechanisms for energy transfer at the cathode. In the very short time frames of EDM, the amended model uses the photoelectric effect rather than positive-ion bombardment as the dominant source of energy supplied to the cathode surface.

Followed by the second series of theoretical models, an erosion model for the anode material was presented (Patel and Dibitonto, 1989). As with the point heat-source in the first model, the second theory also accepts power rather than temperature as the boundary condition at the plasma and anode interface. A constant fraction of the total power supplied to the gap is transferred to the anode. The power supplied was assumed to produce a Gaussian distributed heat flux on the surface of the anode material. Furthermore, the area upon which the flux is incident was assumed to grow with time. In addition for the third series of theoretical models a variable mass cylindrical plasma model (VMCPM) was developed created the spark by electrical discharge in a liquid media (Eubank and Patel, 1993). The model consists of three differential equations-one each from fluid dynamics, an energy balance, and the radiation equation-combined with a plasma equation of state. A thermo physical property subroutine allows realistic estimation of plasma enthalpy, mass density, and particle fractions by inclusion of the heats of dissociation and ionization for a plasma created from demonized water. Problems with the zero-time boundary conditions are overcome by an electron balance procedure. Numerical solution of the model provides plasma radius, temperature, pressure, and mass as a function of pulse time for fixed current, electrode gap, and power fraction remaining in the plasma.

Singh and Ghosh (1999) re-connected the removal of material from the electrode to the presence of an electrical force on the surface of the electrode that would be able to mechanically remove material and create the craters. Based on the research proposed the thermo-electric model is used as a general method of calculating the electrostatic force on the surface of the cathode and the stress distribution inside the metal during the discharge. The result obtained for the stress distribution deep inside the metal, where the surface stress acts as a point force, can be extended for any kind of discharge. The model result was showing the experimental results for short pulses. The proposes of that the electrostatic forces are the major cause of metal removal for short pulses and melting becomes the dominant phenomenon for long pulses and explains the reason for constant crater depth with varying discharge duration, for short pulses.

2.3.2 Electrode Wear Rate

The appearance of the EDM constitutes a true industrial revolution because it is well the first time as a machine which can carry machining with a tool that has an inferior hardness. Electrode wear ratio is known as amount of machining of the workpiece and the amount of electrode wear and it is important on transcribing the shape of the electrode to the workpiece. Electrode wear ratio changes due to the combination of electrode and workpiece material, especially in condition when the polarity is apply due to the voltage, and the duration of the spark. According to the Katz et al., (2005) preceded a research in which the goal is to establish a relationship between the input and the output parameters to create a possible model process. A number of authors have performed the reduce value of electrode wear rate (EWR) is related to the increase the value of material removal rate (MRR) such as Ferreira (2005) who studied the micro machining with copper tungsten electrode and the effect of different parameters such as tension, current of discharge, impulse time and dielectric pressure on the variation of the surface aspect by examining its topography and its microstructure with an electrons scanner. Following over this research electrode wear ratio (EWR) is function as EDM characteristic to measure the ease of machining in the EDM processes by supporting the total energy of discharge pulses which conducted to machine the workpiece and degrades the tool electrode.

The selection of optimized manufacturing conditions is one of the most important aspects to consider in the die-sinking electrical discharge machining (EDM) of conductive steel, as these conditions are the ones that are to determine such important characteristics: electrode wear (EW). The main process parameters are peak current during current supply, its duration or pulse-on-time and the delay interval before next peak, or pulse-off-time, and the average voltage between electrode and workpiece through the gap. Pulse power and energy are determined by the pulse intensity and duration, while the flushing and cooling efficacy depend on the duty factor, ratio between the pulse-on-time and the overall cycle duration. Machining accuracy depends on the electrode tolerances, on the gap between the electrode and the workpiece, which varies with the machining parameters and the local geometry, and on wear. In particular, wear of the electrode along the feed direction can be compensated, but wear along the cross-section turns into part inaccuracy (Khan, 2008). As regards EDM of aluminium alloys Khan (2008) evaluates electrode wear in EDM of aluminium and mild steel. It is claimed that higher thermal conductivity of aluminium leads to comparatively higher energy dissipation into the workpiece than in the electrode, which turns into lower tool wear. As to the EDM surface morphology, Miller and Guha (1998) report that the heat affected layer in aluminium alloys is not harder than the base material and is not susceptible to cracking, unlike what is observed for steel.

2.3.3 Surface Roughness

In discover the effect of surface roughness due to the electro-discharge machine parameter, Rahman et al., (2010) was examined the effects of pulse on time, pulse off time and discharge current on surface roughness of Ti-6Al-4V alloy. Based on the research have found that the pulse-on-time and discharge current have the highest effect on the output parameters of spark machining. However, in investigated the machining of smart materials by copper-tungsten tool (Michelle and Daniel Schodek, 1998) the result have found due to the importance of using smart materials in various industries, the research on the machining operation has a special significance on the impact of machining input parameters such as discharge current, pulse-on-time and pulse-off-time on material surface roughness is investigated for the NiTi60 shape alloy to improve manufacturing industries. Krishna Mohana Rao et al., (2009) developed a hybrid model and optimized the surface roughness in electric discharge machining using artificial neural networks and genetic. The experiments are carried out on Ti6Al4V, HE15, 15CDV6 and M 250. Multi-perceptron neural network models were developed using Neuro Solutions package.

Genetic algorithm concept is used to optimize the weighting factors of the network. Chena et al., (2007) performed Electrical discharge machining of TiNiCr and TiNiZr ternary shape memory alloys and observed that the roughness of EDM surface increases with the discharge current and pulse duration. Based on the observation were found the hardening effect near the outer surface for EDM TiNiX alloys originates from the recast layer. The EDM TiNiX alloys still exhibit a nearly perfect shape recovery at a normal bending strain, but slight degradation of shape recovery occurs at a higher bending strain due to the constrained effect on the TiNiX matrix by the recast layer.

Continued the Yan Cherng Lina et al., (2009) performed on the optimization of machining parameters in magnetic force assisted EDM based on Taguchi method have observed that the machined surface of standard EDM depicted more obvious micro-cracks than that of magnetic force assisted EDM. Petropoulos et al., (2004) have done modelling of surface finish in electro-discharge machining based upon statistical multi-parameter analysis and identified that the mutually independent parameters such as *R*a and *W*a, *R*sk, *R*ku, *β*, *D* are considered to make-up a minimum set for surface texture description regarding both industrial quality control and research. Lin (2002) performed a study on the use of the orthogonal array with grey relational analysis to optimize the electrical discharge machining process with multiple performance characteristic and found that a grey relational analysis of the experimental results of surface roughness can convert optimization of the multiple performance characteristics into optimization of a single performance characteristic called the grey relational grade. Lina et al., (2000) performed the optimization of the electrical discharge machining process based on the Taguchi method with fuzzy logics and found that the performance characteristics such as EWR can be improved through this approach. According to the Kansal et al. (2005) studied the parametric optimization of powder mixed electrical discharge machining by response surface methodology and observed that there is discernible improvement in surface roughness of the work surfaces after suspending the silicon powder into the dielectric fluid of EDM.

Puertas and Luis (2003) conducted a study on the machining parameters optimisation of electrical discharge machining and observed the factor having the most important influence on the surface roughness is the factor of intensity, also it has been observed that there is a strong interaction between the current and the pulse duration factors being advisable to work with high current values and low pulse duration values. Ming-Guo Her and Feng-Tsai Weng (2002) performed a study of the electrical discharge machining of semi-conductor BaTiO3 and understood that for the EDM of semi-conductor BaTiO3 positive polarity machining should be selected to ensure better surface roughness, minimum surface roughness can be achieved using GA, and to avoid