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Process Parameters Optimization in Wire Electrical Discharge Machining of Super Nickel -718 Super Alloy

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ABSTRACT

The Wire Electrical Discharge Machining applied to manufacturing sectors especially in aerospace, ordinance, automobile and general engineering etc. It is one of the non-traditional machining processes which are used for machining of materials difficult to machine in conventional machining. Intricate profiles used in prosthetics, bio-medical applications can also be done in WEDM. It involves complex, physical and chemical process including heating and cooling. The electrical discharge energy affected by the spark plasma intensity and the discharging time will determine the crater size, which in turn will influence the machining efficiency and surface quality. With the introduction and increased use of newer and harder materials like titanium, hardened steel, high strength temperature resistant alloys, fiber-reinforced composites and ceramics in aerospace, nuclear, missile, turbine, automobile, tool and die making industries, a different class of machining process has been emerged. Better finish, low tolerance, higher production rate, miniaturization etc are also the present demands of the manufacturing industries. Compare to Conventional machining EDM process is more efficient but it is difficult to obtain intricate and complex shapes of the components. Initially manufacturer often do not meet the requirements in machining a particular material due to the machine tool tables. For obtaining various shapes of structural components the WEDM process is important in many cases, but it requires the improved machining efficiency. Hence, for improving the machining efficiency it requires the models to predict optimum parametric combinations accurately. But WEDM consists of a number of parameters, which makes it difficult to obtain optimal parametric combinations for machining different materials for various responses like surface

roughness, material removal rate, kerf etc. For achieving optimal machining performance in Electrical Discharge Machining (EDM), it is important to select machining parameters. However, this does not ensure that the selected machining parameters result in optimal or near optimal machining performance for that particular Electrical Discharge Machine and environment. In recent years, WEDM has become an important nontraditional machining process are used in the aerospace and automotive industries. However, selection of cutting parameters for obtaining higher cutting efficiency or accuracy in WEDM is still not fully solved. This is mainly due to the complicated stochastic process mechanisms in Wire EDM. The result says, the relationships between the cutting parameters and cutting performance are hard to model accurately. Super Ni-718 is a nickel-based high-temperature strength super alloy found applications in aerospace, missile, nuclear power, chemical and petrochemical. Heat treatment, marine, and space shuttle components. The characteristics such as higher strain hardening tendency, high dynamic shear strength and poor thermal diffusivity are the major causes of difficulty in machining or this alloy. These in turn, produce higher cutting forces; highly strain hardened and toughened chips. And excessive tool wear and cause surface damages extending to subsurface levels. Besides, various process, Cutting tool and work material-related parameters have complex interactions during machining. Owing to all these problems, it is very difficult to machine Super Ni-718 by conventional machining processes and moreover, by conventionally used tool materials. After a comprehensive study the existing literature, a number of gaps have been observed in WEDM .

Literature review reveals that the researchers have carried out most of the work on WEDM developments, monitoring and control but very limited work has been reported on optimization of process parameters and the effect of machining parameters on WEDM of Super Ni-718 has not been fully explored by using WEDM.

l. Introduction

The development of modern mechanical industry. The demand for alloy materials having high hardness. Toughness and impact resistance are increasing audit required advanced machining process. Nevertheless, such materials are difficult to be machined by traditional machining methods. Hence, non-traditional machining methods including electrochemical machining, ultrasonic machining, electrical discharging machine (EDM) etc. are applied to machine such difficult materials Wire Electrical Discharge Machining (WEDM) process with a thin wire as an electrode transforms electrical energy to thermal energy for cutting materials. With this process, alloy steel, conductive ceramics and aerospace materials can be machined irrespective of their hardness and toughness. Furthermore, WEDM is capable of producing a fine, precise, non-corrosion and wear resistant surface.

WEDM is considered as a unique adoption of the conventional EDM process. Which uses an electrode to initialize the sparking process However, WEDM utilizes a continuously travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05-0.30 mm, which is capable of achieving very small comer radii. The wire is kept m tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining.

1.1. Principle of WEDM process

The WEDM machine tool composes of a main worktable (X-Y) on which the work piece is clamped an auxiliary table (U-V) and wire dove mechanism. The main table moves along X and Y axis and n is driven by the D C servo motors. The travelling wire is continuously fed from wire feed spool and collected on take up spool which moves through the work piece and is supported under tension between a pair of wire guides located at the opposite sides of the work piece. The lower wire guide is stationary whereas the upper wire guide. Supported by the U-V table, can be displaced transversely along U and V -axis with respect to lower wire guide. The upper wire guide can also be positioned vertically along Z-axis by moving the quill. A series of electrical pulses generated by the pulse generator unit is applied between the work piece and the travelling wire electrode, to cause the electro erosion of the work piece material. As the process proceeds, the X-Y controller displaces the worktable carrying the work piece transversely along a predetermined path programmed in the controller. While the machining operation is continuous, the machining zone is continuously flushed with water passing through the nozzle on both sides of work piece. Since water is used as a dielectric medium, it is very important that water does not ionize. Therefore, in order to prevent the ionization of water, an ion exchange resin is used in the dielectric distribution system to maintain the conductivity of water. In order to produce taper machining, the wire electrode has to be tilted. This is achieved by displacing the upper wire guide (along U-V axis) with respect to the lower wire guide. The desired taper angle is achieved by simultaneous control of the movement of X- Y table and U- V table along their respective predetermined paths stored in the controller. The path information of X- Y table and U-V table is given to the controller in terms of linear and circular elements via NC program. Figure1.1 exhibits the schematic diagram of the basic principle of WEDM process (1).

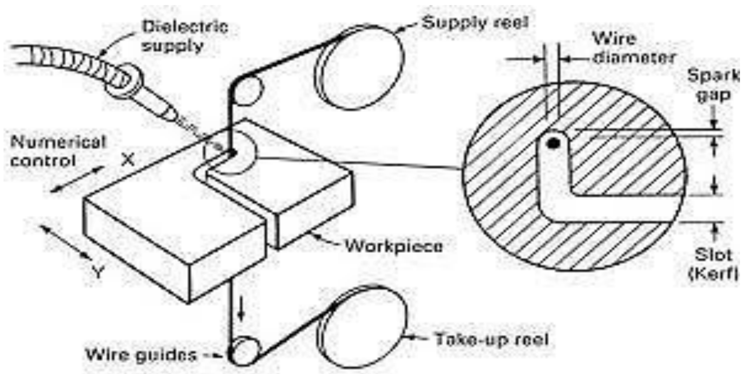

Figure 1.1: Basic principle of WEDM Process.

1.2. WEDM importance

The importance of WEDM process grown enormously since it was first applied more than 30 years ago. The optical-line follower system to automatically control the shape of the components to be machined by the WEDM process is applied in 1974 by D.H. Dulebohn. By 1975, its popularity rapidly increased, as the process and its capabilities were better understood by the industry. The end of the 1970s, when Computer Numerical Control (CNC) system was initiated into WEDM, which brought a major evolution of the machining process (2).

The degree of accuracy of work piece dimensions obtainable and the line surface finishes make WEDM particularly valuable for applications involving manufacture of stamping dies. extrusion dies and prototype parts. Its broad capabilities have allowed it to encompass the production. aerospace and automotive industries and virtually all areas of conductive material machining. This is because WEDM provides the best alternative or sometimes the only alternative for machining conductive, elevated strength and temperature resisting materials, conductive engineering ceramics with the scope of generating intricate shapes and profiles (3).

WEDM has tremendous potential in its applicability in the present day metal cutting industry for achieving a considerable dimensional accuracy, surface finish and contour generation features of products or parts, Moreover, the cost of wire contributes only 10% of operating cost of WEDM process. The difficulties encountered in the die sinking EDM are avoided by WEDM, because complex design tool is replaced by moving conductive wire and relative movement of wire guides.

1.2.1 History of WEDM:

In 1969, the SWISS FIRM 'AGIE' produced the world's first WEDM, the process was fairly simple, not complicated and wire choices were limited to copper and brass only. Early WEDM produced were extremely slow but as more and more research was done WEDM, cutting speed and overall capabilities of WEDM have been modified. In the early 70's a typical machine cut 2 square inches per hour (i.e. 21 mm/min), in the early 80' s, 6 square inches per hour (i.e.64 mm^2/min), however WEDM which are under operation today can cut 20 times faster than these earlier machines.

In recent years, the technology of WEDM has been improved significantly to meet the requirements in various manufacturing need. especially in the precision mold and die industry. WEDM has greatly improved in terms of accuracy, quality, productivity and precision, thus immensely helped the tooling and manufacturing industry. WEDM operated in industry today are equipped with Computer Numerical Control (CNC) which helps in improving efficiency and accuracy [4].

1.3. Material removal mechanism in WEDM

The metal removal in WEDM involves the removal of material due to vaporization and melting caused by the electric spark discharge which generates by a pulsating direct current power supply between the electrodes. In WEDM negative electrode is continuously moving wire and the positive electrode is the work Piece. Between two closely spaced electrodes under the influence of dielectric liquid the sparks will generate. In WEDM, Water is used as dielectric because of its rapid cooling rate and low viscosity. No precise theory has been well- known for the complex machining. However, experimental evidence suggests that the applied voltage creates an ionized channel between the nearest points of the work piece and the wire electrodes in the primary stage. Subsequently, actual discharge takes place with heavy flow of current and the resistance of the ionized channel gradually decreases. The high intensity of current continues to further ionize the channel and a powerful magnetic field is generated. This magnetic field compresses the ionized channel and results in localized heating. Even with sparks of very short duration, the temperature of electrodes can locally rise to very high value which is more than the melting point of the work material due to transformation of the kinetic energy of electrons into heat. The high energy density erodes a part of material from both the wire and work piece by locally melting and vaporizing and thus it is the dominant thermal erosion process.

2.LITERATURE REVIEW

WEDM is an essential operation in several manufacturing processes in some industries, which gives importance to variety, precision and accuracy. Several researchers have endeavored to develop the performance characteristics specifically the surface roughness, dimensional accuracy and material removal rate etc. In this operation the full potential utilization of this process is not totally solved because of its complex and stochastic nature and additional number of variables involved. It is important to know the contribution of different researchers. This chapter describes with the review, on research related to the present work and also the objective of the present work.

2.1. Machining of EDM

An attempt is made [6] to unveil the influence of the machining parameter on the machining performance of WEDM in finish cutting operations. In this work, the gap width, the surface roughness and the white layer depth of the machined work piece surface are measured and evaluated.

The review on the state shows machining of advanced materials by using Die sinking EDM, WEDM, Micro- EDM, Dry EDM AND RDE-EDM [7].[8] Reported the study to select the most suitable cutting and offset parameter combination for the WEDM process in order to get the desired surface roughness value or the machined work pieces.

[9] probe the effect of spark on-time duration and spark on-time ratio on the MRR and surface integrity of four types of advanced material; porous metal foams, metal bond diamond grinding wheels, sintered Nd-Fe-B magnets and carbon-carbon bipolar plates. Regression Analysis was applied to form the wire EDM. MRR, Scanning Electron Microscopy (SEM) analysis was used to investigate the important EDM parameters on surface finish. Machining the metal foams without damaging the ligaments and the diamond grinding wheel to precise shape is very difficult. Sintered Nd-Fe-B magnet material was found very brittle and easily chipped by using traditional machining methods. Carbon-carbon bipolar plate was delicate but could be machined easily by the EDM.

[10] Deals with titanium alloy (Ti-6AI-4V) and applied a data-mining technique to study the effect of different input parameters of WEDM process like cutting speed and SR.

[11] Reported variations of cutting performance with pulse on time, open circuit voltage, wire speed and dielectric fluid pressure used in WEDM process. Brass wire with 0.25mm diameter and AISI 4140 steel with 10 mm thickness were used as tool and work materials in the experiments. Surface roughness and cutting speed measured as performance characteristics. By using an regression analysis method the difference of cutting speed and surface roughness with cutting parameters is sculptled. In addition to that significance of the cutting parameters on the cutting performance outputs is find out by using the variance analysis (ANOVA).

Singh [12] investigated MRR of hot die steel (H 11) by varying different process parameters such as T ON, T OFF, SV, IP, WF and WT and also calculated values for these process parameters to maximize MRR. By experiments it has been found out that wire feed, and Wire tension have no effect on MRR as neutral parameters, simultaneously pulse on time and peak current are directly proportional to MRR. Pulse off time and servo voltage has an inverse relation with the MRR.

2.2. EDM of super alloys

Super Ni is used extremely in aircraft industries and gas turbines. It is found difficult to cut this material by traditional machining process. It is difficult in machining may be attributed to its ability to maintain hardness at elevated temperature which otherwise very useful for hot working in environment. Shorter tool life and severe surface abuse of machined surface are the major problems encountered during machining of nickel based super alloys (Warburton, 1967: field 1965) [13]. Its outstanding high temperature strength and extreme toughness create difficulties during machining due to its work hardening tendency which results in very high cutting forces and significant burr formation during machining. Considering all this formation of complex shapes by this material along with reasonable speed and surface finish is not possible by traditional machining. Therefore, wire electric discharge machining is one of the suitable process to shape this alloy.

2.3. Optimization of process parameters

Optimization of process parameters of EDM has been treated as single objective optimization process and multi objective optimization problem. Taguchi method has been employed by Yusoff et al in 2009[14] as single-objective optimization technique to find the optimal combination of process parameters by considering each performance measure as a separate objective.

Tarng [15] used feed forward neutral network to build the WEDM process model to associate the cutting parameters and the responses consist of machined surface roughness and machining speed. Simulated annealing algorithm is after that applied to the neutral network for solving the optimal cutting parameters.

[16] applied Multi-objective genetic algorithm to multiple objectives of MRR and surface roughness on machining high speed steel. Experiments, based on Taguchi' s parameter design, were carried out to study the effect of different parameters and mathematical models were build up between machining parameters and responses like metal removal rate and surface finish by using nonlinear regression analysis. These mathematical models were optimized multi objective optimization technique obtain a pareto-optimal solution set. These results of optimization shows MRR and surface finish are influenced more by pulse peak current, pulse duration, pulse off period and wire feed than by flushing pressure and wire

tension. Results as well signify that the surface quality decreases as the MRR increases and they differ almost linearly.

[17] attempt to optimize the Kerf in machining of Sic/6061 Al MMC with response surface methodology (RSM). Mathematical model have been build up for response parameter and properties of the machined surface have been studied by using SEM.

[18] Material removal rate study by Statistical analysis of WED rotating. The application of WEDM for machining of accurate cylindrical shape on hard and difficult to machine materials is presented. At first it was introduced that the design of a precise, flexible and corrosion-resistant rotary spindle is submerged. The spindle as machine to rotate the work piece in order to generate free form cylindrical geometries. The process of material removal rate (MRR) is an significant indicator of the effectiveness and cost-effectiveness. Various experiments were performed to consider effects of power, time-off, wire speed, wire tension, voltage, servo and rotational speed on the MRR.

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2.5. MCD Methods of Reviews:

The scoring method selects or assess an alternative to its score (or utility). Utility or score is used to express the decision maker‟s preference. It transforms attribute values into a common preference scale such as [0,1] so that comparisons between different attributes becomes possible. A very popular method in this category is the Simple Additive Weighting method. This method calculates the overall score of an alternative as the weighted sum of the attribute scores or utilities.

The Analytical Hierarchy Process (AHP) is another popular method in this category. This method calculates the scores for each alternative based on pair wise comparisons [19].

The concordance method generates a preference ranking which best satisfies a given concordance measure. This method is believed that an alternative having many highly ranked attributes should be ranked high [20].

3.1. Optimization Methods

Due to very complex nature of WEDM process, selection of favorable process parameters by traditional methods is not satisfactory with reference to improve productivity and accuracy of machining. Majority of researchers, working in the field of WEDM, employed Taguchis method as a single objective optimization technique as it very simple, effective and efficient. (Tzeng and Chen, 2003[21]; Puri & Bhattacharya, 2003[22]; Singh et al., 2007[23]; Bhaduri et aI, 2009[24]). For Multi objective optimization and principal component analysis are/employed by many researchers for better output. This chapter outlines optimization methods which have been employed to obtain the optimal level combination of process parameters for high MRR, low SR and low SG.

3.2. Taguchi's Method

Dr. Genichi Taguchi developed an engineering method of quality improvement referred as *Quality Engineering* in Japan and *Robust Design* in the West. According to the philosophy of Dr Taguchi, deviation from intended value in any of the product feature causes losses to customer, manufacturer and to the society. Therefore, emphasis is given on minimizing the losses by reducing the deviation. In this method, emphasis is given on concept selection and parameter optimization to make the robust product(s) and/or process (es). Robustness is attained by reducing the measured variation of key quality characteristics and ensuring that those quality characteristics can be easily adjusted onto the nominal value. Minimizing difference are building the system less sensitive to variation not only decreases the cost but also develop the quality of the product/process. Taguchi created exclusive metrics called as signal-to-noise ratios, to analyze a system's robustness. These metrics help us to take decisions regarding optimization of product/process models. The eminence of the product/process (i.e. its performance) can vary due to many reasons. The causes of the variability arc called noise factors, Noise factors are responsible for deviation of response or functional characteristics

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4.1. Design of Experiments

There are varieties of S/N ratio characteristics, from its target value Signal-to-noise ratio mainly reflects the variability in the response of a system reasoned by noise factors (25). The selection of problem is specific. The S/N ratio characteristics commonly used in quality engineering are as follows (26, 27).

Nominal-the-better characteristics

$$S/N\ Ratio = -10 \log_{10}(1/n)\Sigma^{n}_{i}= \Sigma/s^{2}_{y} \quad (3.\ 2\ .1)$$

Smaller-the-better characteristics

$$\text{S/N Ratio} = -10 \log_{10}(1/n) \sum_{i}^{n} = y_{ij}^{2} \quad (3.2.2)$$

Larger-the-better characteristics

$$\text{S/N Ratio} = -10 \log_{10}(1/n) \sum_{i}^{n} = 1/y_{ij}^{2} \quad (3.2.3)$$

Where Y is the average of observed data and S is the variance of *y*. Y_i is the experimentally examined value and n is the repeated number of each experiment.

For each type of characteristics, the above S/N transformation, the higher the S/N ratio is better result.

In general purpose tool for quality engineers, Taguchi's main success has been emphasize the importance of quality in design and to simplify the use of experimental design, along with the many criticisms of the Taguchi method is used in the Signal-to Noise (S/N) ratio as a performance measure statistic. The S/N ratios have been criticized as providing deceptive results in certain cases. The functional robustness of product and process is measured by S/N ratio. This is basically because the former is more focused on the statistical aspects whereas the latter is primarily focused on the engineering aspects of quality. Taguchi method lies in the fact that it integrates statistical methods into the influential engineering process.

Taguchi regarded as the foremost proponent of robust parameter design, which is an engineering method for product or process design that focuses on minimizing variation and/or sensitivity to noise. Taguchi proposed many approach to experimental designs that are sometimes called "Taguchi Methods." These methods utilize two- three- four- five- and mixed- level fractional factorial designs. When used properly, Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. The scientist Taguchi refers to experimental design as "off-line quality control" as it is a method of ensures good presentation in the design stage of products or processes.

Taguchi's method has been employed to obtain the optimal level/factor combination of WEDM process parameters for MRR, SR and SG separately by treating each performance measure as single response. The signal-to-noise ratio is used to represent quality characteristic and the largest S/N is demanded. Larger-the-better and smaller-the-better methodology of S/N is taken for MRR, SR and SG respectively.

The word 'design' in the term design of experiments, is used in a sense to convey planning of experiments to complete intended objectives. To design the experiment is to build up a scheme or layout of the different conditions to be studied. By performing, 'design' refers to some form of engineering communication, such as a set of specifications, drawings or physical models that explain the concept. Experimentation is an fundamental part of any engineering investigation. The word 'design', in engineering, may be product design or the process design. Since an experiment design should satisfy primarily conditions for each experimental run. So, before designing an experiment, information of the product/ process under investigation is of the prime importance for identifying the factors that influence the outcome. An arrangement of levels of all the factors involved in the experiment is called a treatment combination. The common scenario in an experiment is that there is an output variable, which depends on several input variables, called factors. Each factor has at least two settings, called levels. Simultaneously to study the effects of multiple variables on performance measures is used by statistical technique of Design of Experiments (DOE) . It provides an capable experimental schedule and statistical analysis of the experimental results. The following four approaches have been in use as DOE (Fowlkes and Creveling 1998):

- Build-test-fix
- One-factor-at-a-time experiments
- Full factorial experiments
- Orthogonal array experiments (fractional factorials)

Build-test-fix is strongly dependent on skill and luck of experimenter. II is an ineffective and inefficient method that leads to long cycle times and poor reproducibility.

A **one-factor-at-a-time experiment** is the traditional method in which one factor is thoroughly studied under fixed conditions of other factors. Once one factor is well characterized, other factor is studied thoroughly by keeping the other factors fixed. This process is continued for characterization of all factors. This approach has two weaknesses: (i) slow nature (ii) inability to access interactions among the factors.

The technique of laying out the conditions designs) of experiments involving multiple factors was first proposed by the Englishman, Sir R.A. Fisher(1920). This process is known as the factorial design of experiments. A factorial design will identify all possible combinations for a given set of factors. Many industrial experiments generally involve a significant number of factors, a full factorial design results in a large number of experiments For example, in this experiment showing eight factors, each at two levels, the total number of combinations will be 256. Partial factorial experiment method is used which selects only a small set from all possible set of experimental runs. But the lack of guidelines for its application or the analysis of the results obtained by performing the experiments limits its application in real intelligence. To decrease the number of experimental runs to a practical level.

Taguchi build a special set of designs for factorial experiments that conquer the draw backs of partial factorial experiment. In this method, it clearly defines orthogonal arrays, each of which can be used for many experimental situations. It also provides a standard method for analysis of results. It provides constancy and reproducibility that is generally not found in other statistical method (64). The method is generally known as Taguchi's method. The special set of designs consists of Orthogonal Arrays (OA). The OA is a method of setting up experiments that only requires a fraction of full factorial combinations. The action combinations are chosen to provide satisfactory information to determine the factor effects by using the analysis of means. Orthogonal refers to the balance of the various combinations of factors so that no one factor is given more or less weight in the experiment than the other factors and also refers to the fact that outcome of each factor can be mathematically assessed independent of the effect of the other factors.

The advantages of design of experiments are as follows:

- Numbers of trials is significantly reduced.
- The -process can be identified as an important decision variables which control and improve the performance of the product.
- The parameters of Optimal setting can be found out.
- Parameters of Qualitative estimation can be made.
- Experimental error can be calculated.
- The effect of parameters on the characteristics of the process can be.

5.1. Process Parameters Optimization

The process parameters optimization using Taguchi method, FAHP and TOPSIS. The experimental results of process parameters optimization is presented consequently in the following sections. The experiments was selected and conducted to investigate the effect of process parameters on the response characteristics for example current rate, surface roughness, dimensional deviation.

5.2. Optimum process parameters by using Taguchi method

The effects of WEDM process parameters, on the selected response characteristics current rate, surface roughness and dimensional deviation discussed in this section. The WEDM were conducted by using the parametric advance of the Taguchi's method. The average value and S/N ratio of the response characteristics for each parameter at different levels were calculated from experimental data. The response curves are used for examining the parametric effects on the response characteristics. The main effects of process parameters for raw data and S/N data were plotted. The Analysis of Variance (ANOVA) of raw data and S/N data is approved to identify the important parameters and to calculate their effects on the response characteristics. The most sympathetic values of process parameters of mean response characteristics are established by analyzing the response curves and ANOVA tables.

5.3. Selection of orthogonal array and parameter assignment

The 6 process parameters at three levels have been decided. It is attractive to have 3 minimum levels of process parameters to reproduce the true behavior of output parameters of study. The process parameters are renamed as factors and they are given in the adjacent column.

Table 5.1. Process parameters and their levels

Factors	Input parameters	Level-I	Level-II	Level-III
A	PON	105	115	120
B	POFF	50	55	60
C	PC	70	150	230
D	SF	2100	2120	2140

5.4. Experimental data

The effect of WEDM were conducted to study the process parameters over the output response characteristics with process parameters and connections assigned to columns as given in table 6.2. The results of MRR , RA and DD are given in the table. (27) Experiments were conducted using Taguchi experimental design methodology and each experiment was simply repeated three times for obtaining S/N values. In the present study all the designs, plots and analysis have been carried out using Minitab statistical software.

Table 5.2. Perform the experiments for above combination of input parameters, obtain performance values

EXP.NO.	Cutting rate(mm/min)	Surface roughness(μm)	Dimensional deviation(%)
1	1.23	2.56	0.289
2	0.72	1.72	0.395
3	1.59	2.32	0.287
4	0.38	1.39	0.32
5	0.89	2.2	0.123
6	0.31	1.46	0.533
7	1.72	2.59	0.268
8	1.7	2.32	0.37
9	1.23	2.56	0.289

5.5. Effect on cutting rate

The effect of process parameters on the cutting rate, experiments were conducted using L9 (Table 6.2). The average values of cutting rate for each parameter at levels 1, 2 and 3 for S/N data and raw data are plotted in Figures 6.1 and 6.2 respectively.

From the figures 6.1 and 6.2 shows that the cutting rate increases with increase of PON and decreases with increase in POFF, PC and SF. As the discharge energy increases with the pulse on time and peak current to faster cutting rate. Since the response at various levels of process parameters for given level of parameter value are equal.

MRR mm/min versus PON, POFF, PC and SF: Taguchi Analysis

Table 5.3. Response Table of Signal to Noise Ratios

Larger is better

Level	TON	TOFF	PC	SF
1	-0.8341	-3.6231	-0.2157	-1.6012
2	-0.1280	-0.1771	1.7880	-0.5339
3	-3.9005	-1.0624	-6.4348	-2.7274
Delta	3.7725	3.4461	8.2227	2.1935
Rank	2	3	1	4

Table 5.4. Response Table for Means

Level	Pulse on time	Pulse off time	Peak current	Servo feed
1	1.0467	0.7333	1.0100	0.8433
2	1.0300	1.0833	1.2767	1.1767
3	0.7067	0.9667	0.4967	0.7633
Delta	0.3400	0.3500	0.7800	0.4133
Rank	4	3	1	2

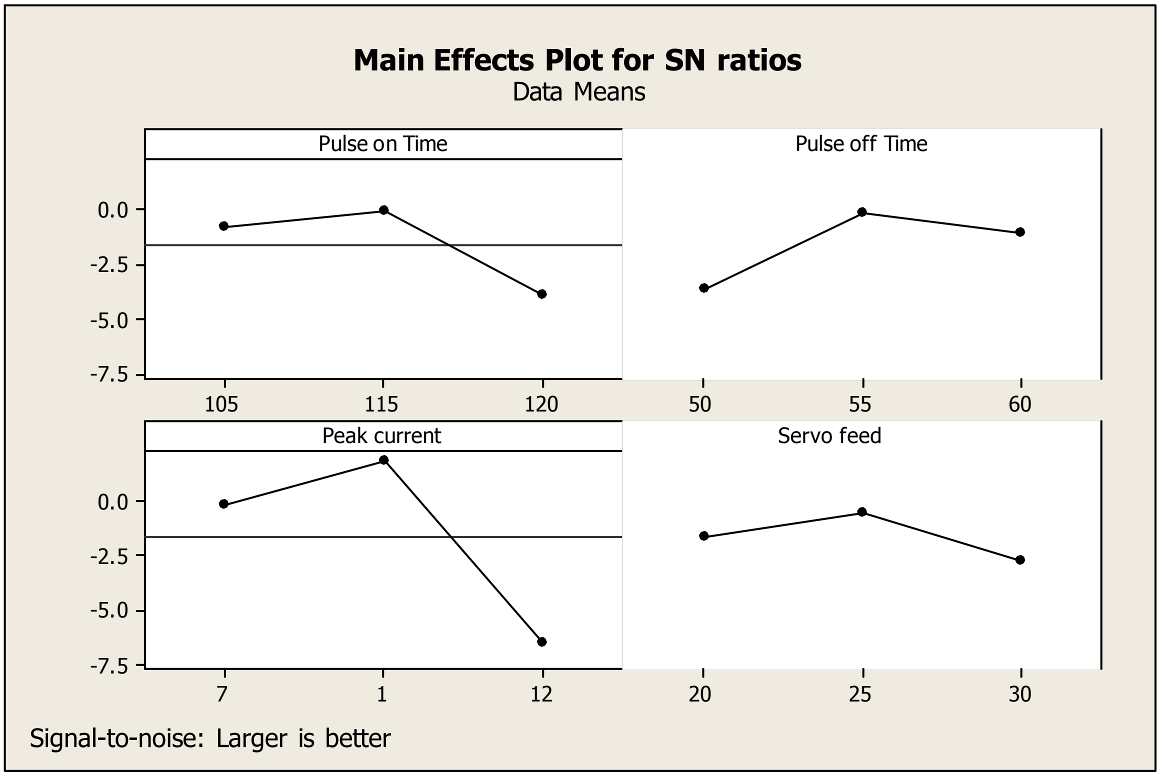

Figure.5.1. Main Effects Plot for SN ratios

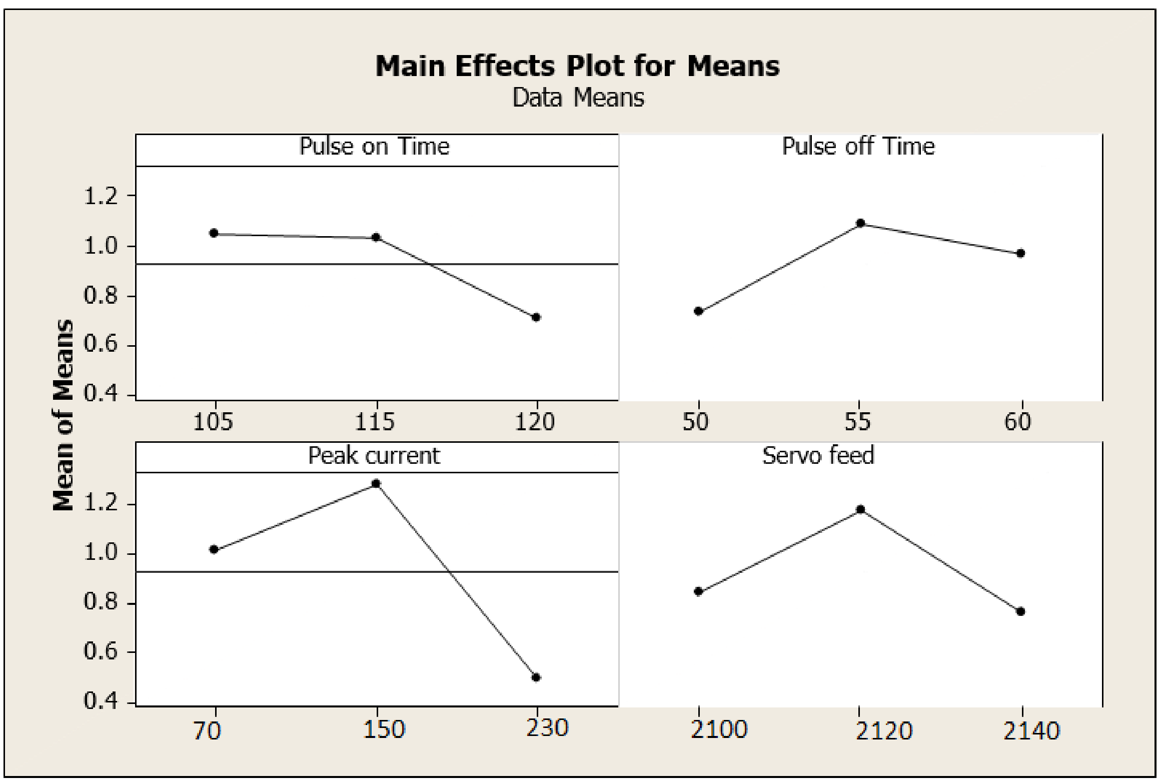

Figure:5.2. Main Effects Plot for Means

Table: 5.5. ln(MRR) versus ln(Pon), lndf(Poff), ln(PC), ln(SF): Regression Analysis

ln(MRR) = 35 + 0.47 ln(Pon) – 0.49 ln(Poff) + 0.294 ln(PC) – 4.8 ln(SF)

Predictor	Coefficient	SE coefficient	T	P
Constant	35.3	290.5	0.12	0.909
ln (Pon)	0.470	5.220	0.09	0.933
ln (Poff)	-0.491	3.904	-0.13	0.906
ln (PC)	0.2938	0.5909	0.50	0.645
ln (SF)	-4.84	37.74	-0.13	0.904

S = 0.872146   R-Sq = 6.7%   R-Sq(adj) = 0.0%

Table 5.6. Analysis of variance

Source	DF	Sum of Squares	Means sum of squares	F	P
Regression	4	0.2187	0.0547	0.07	0.987
Residual error	4	3.0426	0.7606		
Total	8	3.2613			
DF-Degree of freedom, SS- Sum of squares, MS- Mean squares, F-Ratio of variance, P-determines significance of a factor at 95% confident level.					

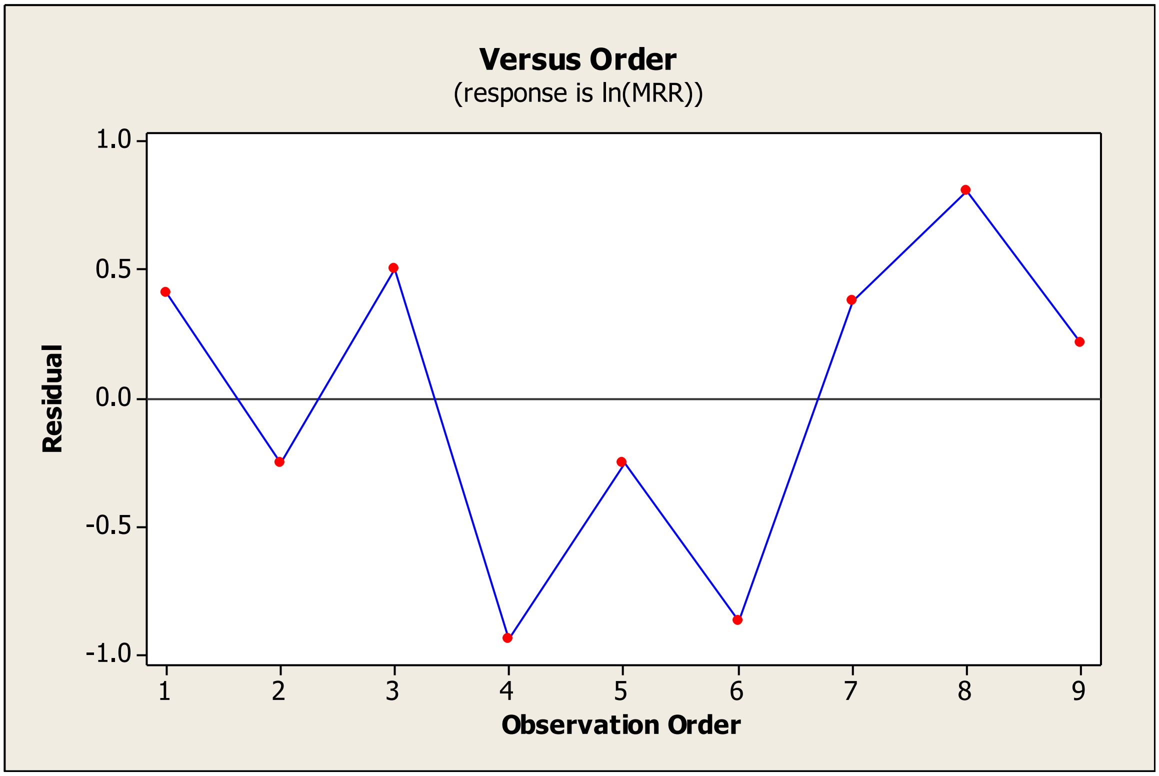

Figure 6.3. Residual Versus Order

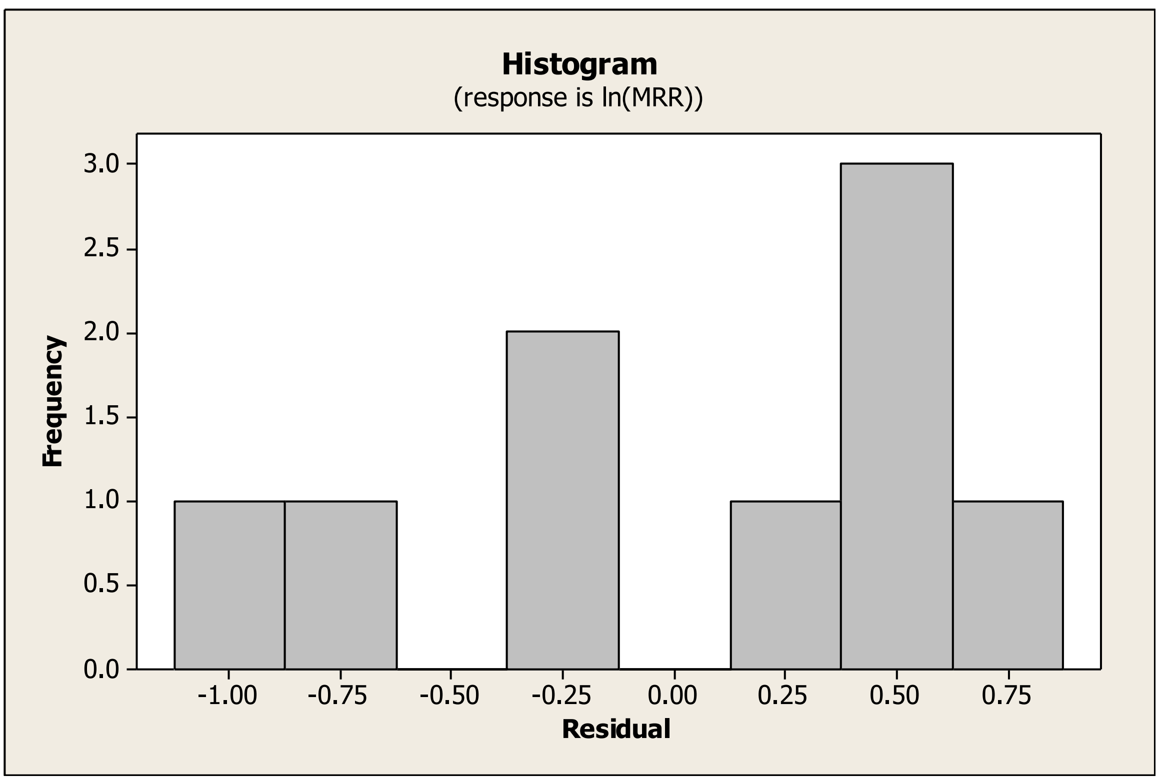

Figure 5.4. Frequency Histogram

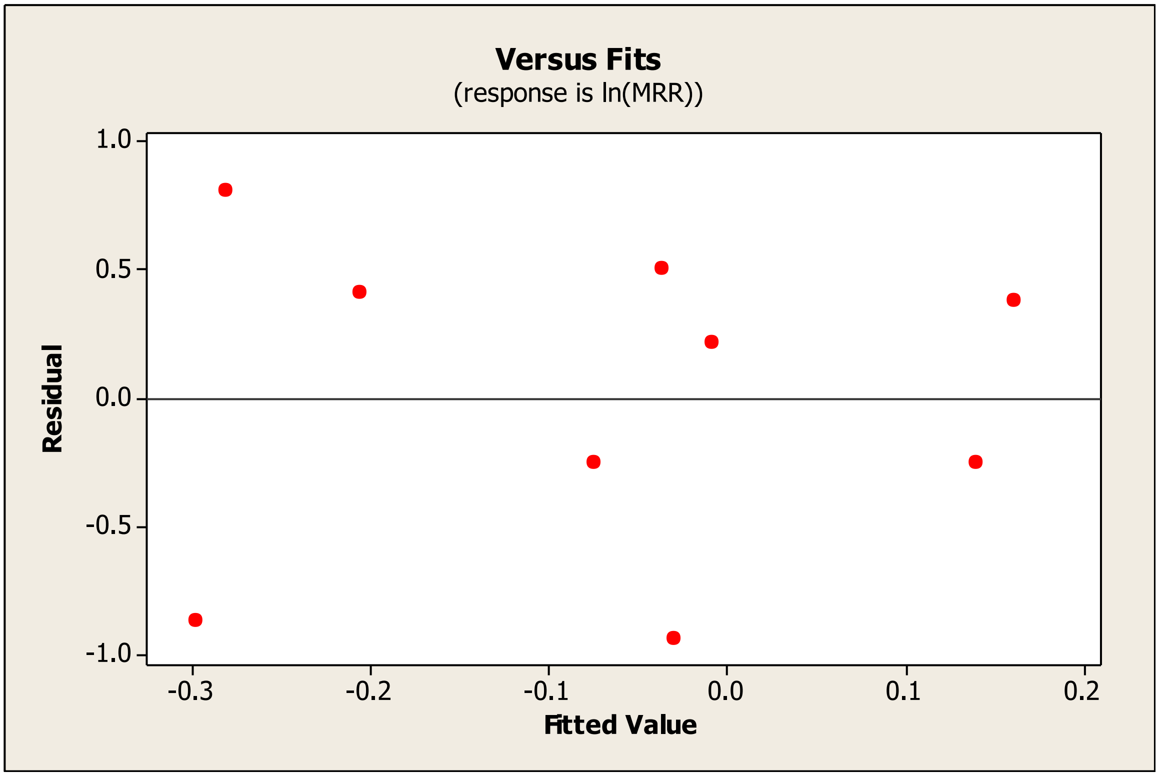

Figure 5.5. Residual Versus Fits

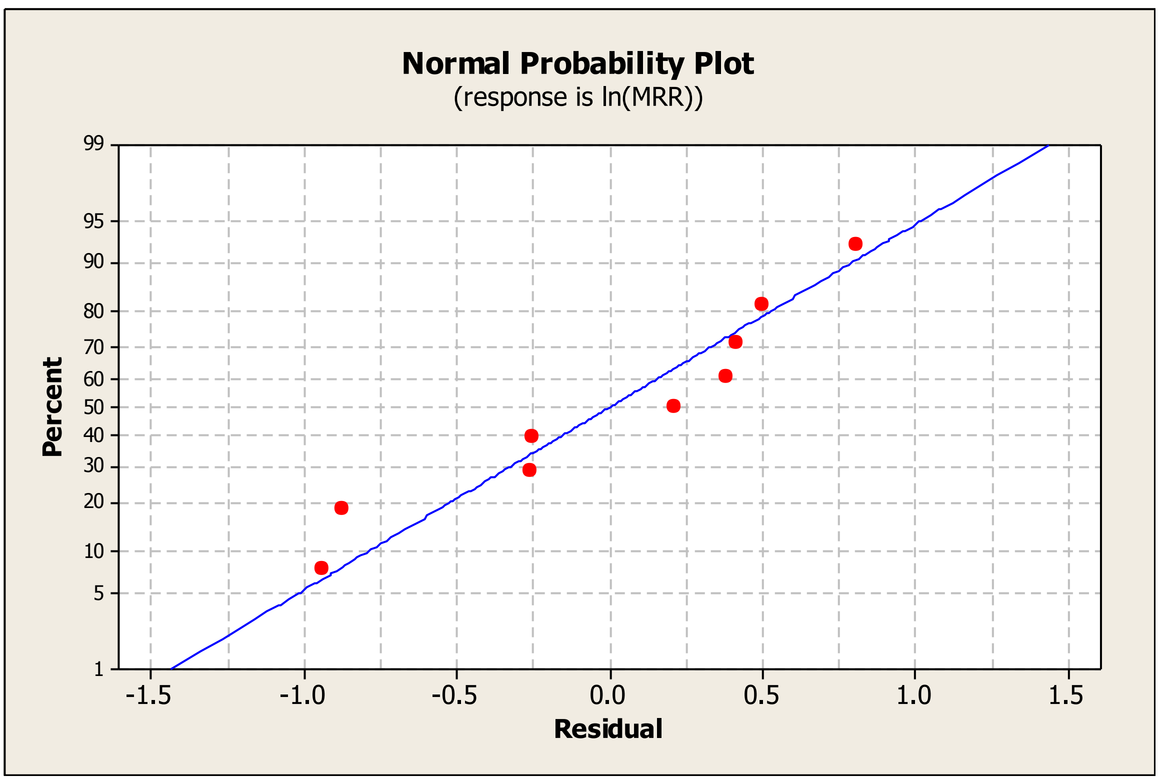

Figure 5.6. Normal Probability Plot

6.1.Results

The present work is focused on optimization of process parameters in wire electrical discharge machining of Super Ni-718. A number of experiments were carried out with the wide range of process parameters. Taguchi`s design of experiments has been employed for design of experiment. Taguchi`s method has been employed has single objective optimization technique to find the optimal combinations of process parameters for each response characteristics. Analysis of Means and S/N ratios has been employed for experimental investigations. For multi response optimization, combined FAHP and TOPSIS analysis have been employed.

6.2.Results

- Super Ni-718 can easily be machined on WEDM with reasonable cutting speed and surface finish. It is intricate to Super Ni-718 on conventional machining because of its outstanding high temperature strength and extreme toughness.
- The important process parameters affecting the WEDM of Super Ni-718 have been identified as Pulse on time for response MRR.
- The important process parameters affecting the WEDM of Super Ni-718 have been identified as pulse off time for response SR.
- As per Taguchi`s analysis the important process parameters affecting the WEDM of Super Ni-718 have been identified as wire Pon by using Brass wire.
- FAHP-TOPSIS analysis has been employed as multi objective technique for parametric optimization of WEDM. On the basis of experimental data PON-2, POFF-1, PC-2, SF-3 is recommended as optimum factor for WEDM of Super Ni-718.
- The process parameters of optimal factor/level combination for MRR are obtained by employing Taguchi‟s method as single objective optimization technique.PON-2, POFF-2, PC-2, SF-2 are recommended.
- Optimal factor/level combination of process parameters for SR is obtained by employing Taguchi‟s method as single objective optimization technique.PON-1, POFF-2, PC-3, SF-1 are recommended.
- For DD Optimal factor/level combination of process parameters are obtained by employing Taguchi‟s method as single objective optimization technique.PON-3,

POFF-2, PC-1, SF-3 are recommended.

6.3.Scope for future work

The effect of process parameters such as conductivity of wire diameter, wire material type, dielectric fluid, work piece height etc., also be investigated.

Evolutionary algorithms like optimization technique, genetic algorithm, particle swarm optimization technique may employed as multi objective optimization techniques to find the better solutions.

Hybridization of some obtainable optimization techniques may be developed and employed like Taguchi and particle swarm, neural network and particle swarm etc.

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