OPTIMIZING THE MACHINING PARAMETERS OF WIRE CUT EDM MACHINE USING TAGUCHI'S DOE TECHNIQUE

Thesis submitted in partial fulfilment of the requirements for

the award of the degree of

MASTER OF ENGINEERING IN MECHANICAL ENGINEERING

(INDUSTRIAL ENGINEERING)

of BHARATHIAR UNIVERSITY

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This is to certify that this thesis work entitled " **OPTIMIZING THE ACHINING PARAMETERS OF WIRECUT EDM MACHINE USING AGUCHI'S DOE TECHNIQUE"** being submitted by **C. K. JAGANNATHAN** eg. No. 0137H0009) for award of the degree of **MASTER OF ENGINEERING MECHANICAL ENGINEERING (INDUSTRIAL ENGINEERING)**, is a bonafide ork carried under my guidance. The results embodied in this thesis have not een submitted to any other University or institute for the award of any Degree or iploma.

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Professional Wirecutting &
Spark Errosion Services

PROJ-TRG
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TO WHOM SO EVER IT MAY CONCERN

This is to certify that **Mr.C.K.JAGANNATHAN**, doing final year ME (Industrial Engineerring) at Kumaraguru College of Technology – Coimbatore, has a done a project in our organization.

The details are :

Title of the Project	:	**OPTIMIZING THE MACHINING PARAMETERS OF WIRE CUT EDM MACHINE USING TAGUCHI'S DOE TECHNIQUE**
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We wish him the very best for a bright future.

R.SHANMUGAM
DIRECTOR

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SYNOPSIS

SYNOPSIS

In the present scenario of liberalization, privatization and globalization there is immense competition among the industries. Only the fittest among them will survive. Quality and productivity are important factors governing the success of any industry. They are two sides of the same coin and cannot be compromised for each other's sake.

An attempt is made in this project to optimize the machining parameters of wire cut EDM machine to achieve minimum surface roughness along with maximum cutting speed.

Wire cut EDM is a machine using modern technology used to cut complicated shapes with high accuracy. The machining parameters were studied and about seven parameters were identified to be concerned with factors affecting the surface finish & cutting speed. The parameters are optimized to obtain minimum surface finish and maximum cutting speed.

The methodology adopted to solve the problem is design of experiments coined by Dr.Genichi Taguchi. The experiments were conducted for steel and copper plate. The results are analyzed using a specialized software called QUALITEK-4 . The ANOVA analysis is carried out to identify the factors influencing the surface roughness and cutting speed. The analysis revealed that about four factors were having more influence on the response.

The parameters are optimized and the optimum conditions for getting minimum surface roughness vary directly with the optimum conditions for maximum cutting speed.

Contents

CONTENTS

INTRODUCTION

INTRODUCTION

In earlier days manual lathes, milling & grinding machines were used for machining precision & close tolerance jobs. It was time consuming and skilled operators were required. But today in competitive world customers needs & requirements are changing day to day. In order to survive in competitive environment the manufacturers should adopt modern technologies. Wire cut EDM process is such as modern technology which finds wide applications in metal cutting industry.

Wire Cut EDM Process is a nontraditional machining technique widely used in Tool & Die making Industry. The process eliminates other machining process like milling, turning etc because the complex profiles can be easily machined & accuracy is high. The problems like chip formation, distortion on the surfaces are eliminated.

The problem faced with the process is finding the combination of machining parameters to attain better surface finish of the machined parts and also maximum cutting speed to increase the productivity.

The thesis deals with a real time problem faced in the tool and die making industry, where the precision components for press tools and mould bases are machined by wire cut EDM process. The accuracy & surface finish are the most important aspect in this area. An effort has been taken to improve the surface finish of the parts machined in this machine. The project was done at M/s Covai EDM Tools Pvt Ltd.

1.1 INTRODUCTION ABOUT THE ORGANIZATION

Covai EDM Tools PVT LTD was established in year 1995. It was established to manufacture tools & mould bases for all types of components. The company was one among to introduce wire cut EDM machine in Coimbatore, in short span of time it grew to the positions of a leader in the field by maintaining quality levels.

The services provided by the company are

1. Wire cutting
2. Spark erosion
3. Tool & die making
4. Consultancy services.

The other plant of organization M/s COVAI EDM FINE PRODUCTS is first to introduce EDM drilling machine in Coimbatore. A separate tool room is established in this plant & spare capacity is also afford to other industries. The leading tool and die making industries, automobile parts manufacturers are main customers of the company. At present the parent company is concentrating on introducing total productive manufacturing concepts in the company.

LITERATURE SURVEY

BASIC CONCEPTS OF TAGUCHI TECHNIQUES

2.1 INTRODUCTION

Quality Engineering is an engineering optimization strategy developed by Dr.Genichi Taguchi. He formed a philosophy by combining the statistics and engineering methods to achieve improvement in quality and costs by optimizing and process designs. Basically quality engineering deals with activities performed for the purpose of reducing the variability in product or process function and the robust design principles so developed becomes only relevant for off-time quality engineering whereas activities are performed upstream in the life of a product or process.

Taguchi method of product or process optimization consists of three phases : concept or system design, parameter design and tolerance design. The parameter design stage itself is totally independent and self-sufficient to be applicable for any parametric optimization study of a process.

Taguchi method of optimization is based on the additive model where interactions among the control factors are not considered. This leads to the notion that this method cannot be applied universally. In this project work an attempt is made to apply Taguchi's design of experiment technique to Wire-cut Electrical Discharge Machining process.

TAGUCHI APPROACH TO QUALITY:

According to Dr. J.M. Juran (1964) quality is "fitness for use" Philip Crosby the leading promoter of the "zero defects" concept and the author of quality is Free (1979), defines Quality as "Conformance to Requirements" [5]. Dr. Deming says that quality should be aimed at the need of the customer, present and future.

American Society for Quality Control (1983) defines quality as "the totality of features and characteristics of a product or service that bear or its ability to satisfy given needs" (1983). According to Genichi Taguchi quality [1] is the loss a product causes to society after being shipped, other than any losses caused by its intrinsic functions".

Quality Loss:

Product quality has been measured by comparing critical product characteristics to engineering specifications for the product [1]. Product specification are still important, but the focus today is more on controlling process characteristics, Since it is the production processes which determine the quality of the finished products. To reduce process and product variability more quality characteristics are selected and made close to target values. This results in reduced quality loss.

Quadratic Quality / Loss Function

This loss function [6] clearly shows that as characteristic moves further away from a target value, an increased loss is incurred. We would need to know the actual losses for some selected values of the characteristic when designing engineering experiments in order to determine the exact form of the loss function. The important point is that it is to improve quality, or to decrease loss. We must strive to have process and product characteristics as close to their target values as possible.

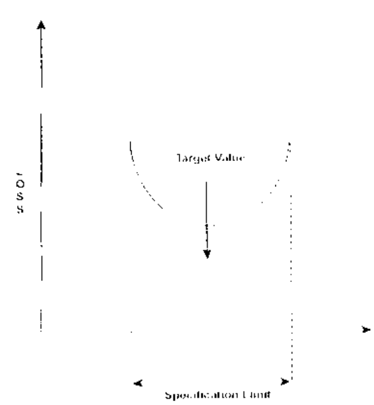


Figure 1 Taguchi loss function

TABLE 1 TAGUCHI'S QUALITY SYSTEM :

OFF-LINE QUALITY CONTROL	**Stage 1** **PRODUCT DESIGN**	**Concerns :** 1. Identify customer needs and expectations 2. Design a product to meet customer needs and expectation. 3. Design a product which can be consistently and economically manufactured.	**QA Steps:** 1. System design 2. Parameter design 3. Tolerance design
	Stage 2 PROCESS DESIGN	**Concerns :** 1. Develop clear and adequate specification producers and equipment for manufacture	**QA Steps :** 1. System design 2. Parameter design 3. Tolerance design
ON-LINE QUALITY CONTROL	**Stage 1** **PRODUCTION**	**Concerns :** 1. Manufacture products with in specifications established during product design using Procedures developed during process design	**Form 1** Process diagnosis and Adjustment Form 2 Prediction and correction **Form 3** Measurement & action
	Stage 2 **CUSTOMER RELATIONS**	**Concerns :** 1. Provide service to customers and use information on field problems to improve products and manufacturing process designs.	**Actions :** 1. Repair, replacement or refund 2. Feed back information on fields Problems. 3.Change product and process specifications / design.

Production / quality system cycle:

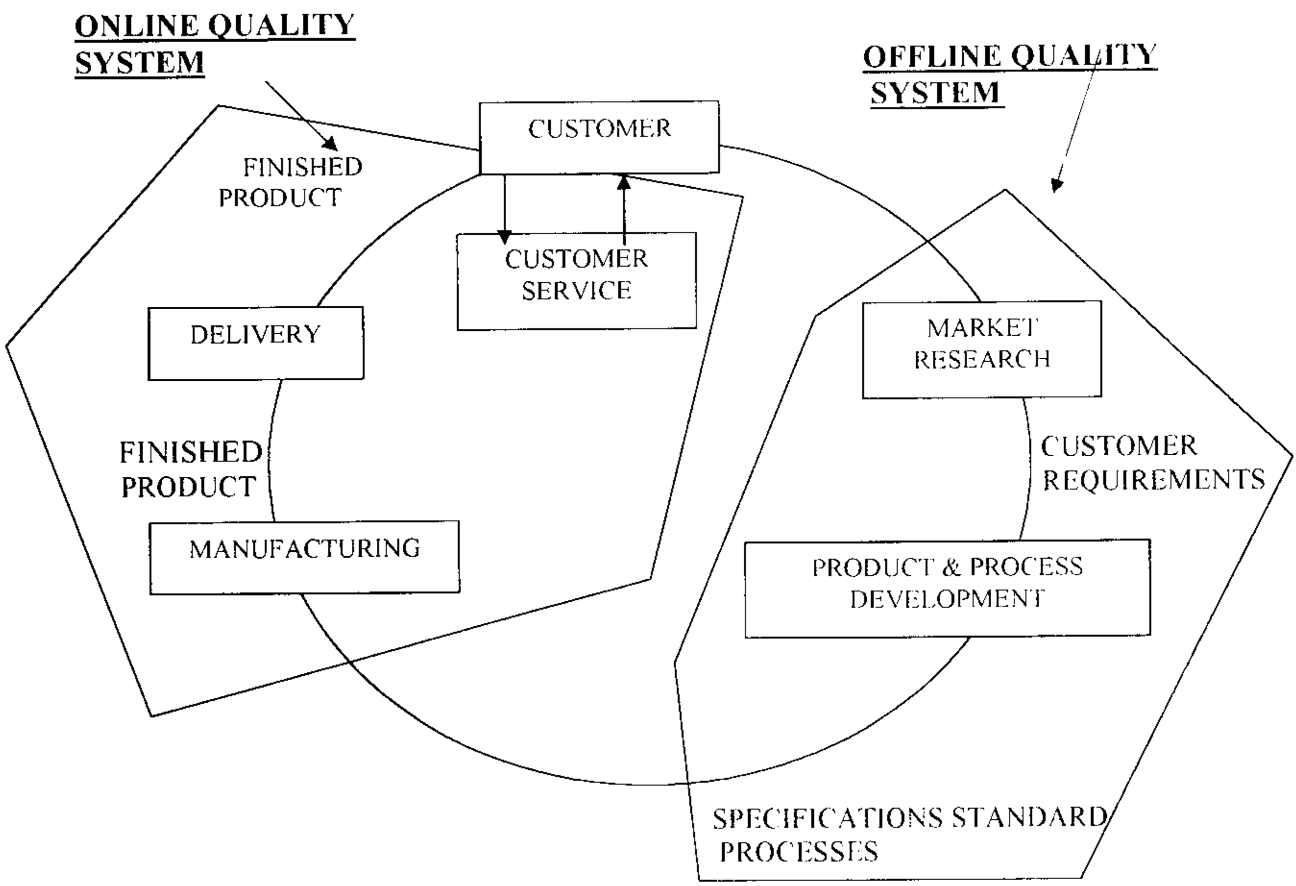


Figure2 Production / Quality system Cycle

Taguchi Quality System:

Quality frequency [5] divides quality system into two parts: quality of design and quality of conformance. Taguchi refers to these two parts as off line quality control and on line quality control.

Off line quality control concerned with:

1. Correctly identifying customer needs and expectations.
2. Designing a product, which will meet customer expectations.
3. Designing a product, which can be consistently and economically manufactured.
4. Developing clear and adequate specifications, standard procedures and equipment for manufacturing.

Stages in off line quality control:

(a) Product design stage.

(b) Process design stage.

During product design stage a new product is developed or an existing product is modified. The goal here is to design a product, which is manufactured and will meet customer requirements. During the process design stage, production and process engineers develop manufacturing processes to meet the specifications developed during the product design stage.

Activities 1, 2, and 3 are part of product design; other activity takes place during the process design stage. Taguchi developed a three-step approach for assuring quality with in each of the two stages of off line quality control. These steps are normally called system design, Parameter design and tolerance design.

On Line Quality Control

It is concerned with manufacturing products with in the specifications established during product design using the procedures developed during process design [5]. Also, Product and process designs may be revised if feed back from customers reveals opportunities for improvement.

Stages of on line quality control:

Production quality methods are of three forms and they are

1. Process diagnosis and adjustment.
2. Prediction & correction
3. Measurement & action.

Optimization:

The exact dictionary meaning for optimization [7] is "Extracting the best thing from the available choices". The optimization means most economical one, in general optimization means minimizing. Depending upon the objective function the optimization may be also maximized.

(a) If objective function is profit (or) accuracy, the optimization is maximization.

(b) If objective function is time, cost etc, then optimization is minimization. The technical word optimize is more stronger than improve or enhance.

Flash Back of the Word Optimization:

In 18th century the famous philosopher cum mathematician Leibeiz coined the word "optimum". In Latin optimius means "Best" optimius contains the name of "ops" the Sabine goddess of agricultural [7]. The rich aristocracy is known as "optimates". The same word used at Oxford University as a title for outstanding scholars.

Optimization as an Engineering Tool:

Optimization is very much useful for engineers, economist and administrators. A good engineer should have some economical sense and administrative capabilities. Optimization is one of the topic under operations research. Operations research is a division of mathematics, which gives more practical solution to day to day problems as well as engineering problems.

Optimization has various definitions. Some of the important definitions are,

1. Optimization is "improving upon the things" those we have chosen.
2. Optimization is "maximizing profit" or "minimizing loss".
3. Optimization is "most economical one of all possible solutions".
4. Optimization means "how to get more profit with minimum effort".

Application of Optimization [7] in Engineering Fields:

1. Design of aircraft and aerospace structures for minimum weight
2. Selection of machining conditions in metal cutting process for minimum production cost.
3. Minimum weight design of structures for earthquake, wind and either types of loading.
4. Shortest route taken by a sales man visiting different cities.
5. Planning of maintenance and replacement of equipment to reduce operating costs.
6. Allocation of resources or services among several activities to maximize the benefit.
7. Planning the best strategy to obtain maximum benefit in the presence of competitor.

2.2 EXPERIMENTAL DESIGN TECHNIQUES:

Experimental designs were used to identify which combination of settings or levels for certain key factors produced the best average value for the product or process characteristics of interest [3].

In the Taguchi approach to quality engineering the primary role of experimental design is to make the process and product insensitive (Robust) to variation in uncontrolled factors.

Experiment:

Experiment is a series of trials or tests, which produce quantifiable outcomes. An experiment where the outcome can be completely predicted in advance is then called a "deterministic experiment". Industrial experiments are generally performed to explore, estimate, and confirm.

- Exploration
- Estimation
- Confirmation

Exploration:

Gather data to learn more about process or product characteristic.

Estimation:

Use data to estimate the effects of certain variables on other variables.

Confirmation:

Gather data to verify a hypothesis abut a relationship among variables.

Experimental design techniques:

Statisticians by themselves do not design experiments, but they have developed a number of structured schedules called experimental designs, which they recommend for taking measurements [3].

These designs have certain rational relationships to the purpose, needs, and physical limitations of experiments design also offer certain advantages in economy of experimentation and provide straight forward estimates of experimental effects and valid estimates of variance.

There are a number of ways in which experiment designs might be classified, for example.

1. By the number of experimental factors to be investigated.
2. By the structure of the experimental design (e.g.. blocked, factorial, nested or response surface design)
3. By the kind of information the experiment is primarily intended to provide (e.g.. estimates of effects, estimates of variance)

Basic terminologies in experimental design:

Factor:

A factor [4] is one of the controlled or uncontrolled variables whose influence upon a response is being studied in the experiment. A factor may be quantitative e.g.. Temperature in degrees, time in seconds. A factor may also be qualitative e.g.. different machines, different operators, switch on or off.

Levels:

The level of a factor are the values of the factor being examined in the experiment. For quantitative factors, each chosen value becomes a level. e.g. if the experiment is to be conducted at four different temperatures then the factor temperature has four levels. In case of qualitative factors, switch on or off become two levels for the switch factor.

Treatment:

A treatment is a single level assigned to a single factor during an experimental run. A treatment combination is the set of levels for all factors in a given experimental run.

Experimental units:

The experimental units consist of the objects, materials or units to which treatment are being applied. They may be biological entitles, natural materials, fabricated products etc.

Experimental design:

The formal plan for conducting the experiment is called experimental design.

Block:

A factor in an experimental program that has influence as a source of variability called block. A block is a portion of the experimental material or of the experimental environment that is likely to be more homogeneous within it than between different portions.

Important tools of experimental design:

Blocking: (planned grouping)

Beyond selected factors for study [1], there are often other background variables that may also influence the outcomes of the experimental program.

Variables such as raw material batches, operators, machines or days the influences of these variables upon the response are not under the control of the experimenter. These variables are commonly called blocks.

When an experimenter is aware of blocking variables it is often possible to plan experimental programs to reduce their influence. In designing experiment, wide use of the reduced variability occurring within blocks to use is made of the reduced variability occurring with in blocks to accentuate the influences of the studied factors. Designs that make use of this uniformity within block are called blocked designs and the process is called planned grouping.

Randomization:

The sequence of experiments and or the assignment of specimens to various treatment combinations in a purely chance manner is called randomization. Such assignment increases the likelihood that the effects of uncontrolled variables will balance out.

Replication:

Replication is the repetition, the rerunning of an experiment or measurement in order to increase precision or to provide the means for measuring precision, replication provides an opportunity for the effects of uncontrolled factors or factors unknown to the experimenter to balance out and thus, through randomization acts as a bias- decreasing tool. Replication also helps to detect gross error in the measurement. Rerun experiments are commonly called replicates.

Reproducibility and repeatability:

Reproducibility measures the variability between items manufactured on different days on different machines. Repeatability measures sources of variability that are more local or immediate assignable to items measurements or the variability occurring between adjacent items manufactured in sequence.

ANOVA:

The knowledge of the contribution of individual factors is a key to decide the nature of the control to be established on a production process. The analysis as variance is the statistical treatment most commonly applied to the results of experiment to determine the percent contribution of each factor. Study of the ANOVA table for a given analysis helps to determine which of the factors need control and which do not.

The ANOVA computes quantities known as sum of squares, degree of freedom, percent contribution etc.

Pooled ANOVA:

When contribution of a factor is small, the sum of squares for that factor is combined with error sum of squares. This process of disregarding the contribution of a selected factor and subsequently adjusting the contributions of the other factor is known as pooling. Pooling is usually accomplished by starting with smallest sum of squares.

Quality Characteristics :

Quality characteristics indicates the direction of desirability of evaluating numbers. Depending on the criteria and how it is measured quality characteristics can be bigger the better, smaller the better or nominal the best. In case for surface finish the surface roughness value should be minimum so the smaller the better characteristics should be selected and for cutting speeds the bigger the the best is selected.

Wire Cut EDM Machine

WIRE CUT EDM MACHINE

3.1 INTRODUCTION

The traditional machining process that involve compression & shear, chip formation have a number of inherently adverse characteristics & limitations. Chip formation can be an expensive & difficult process, large amount of energy is utilized in unwanted products like chips. Further expenditure of energy & money is required to remove these chips from the machines and to dispose or recycle them.

A large amount of energy ends up as undesirable heat, which often produces problems like distortion and surface cracking. Cuttings forces create problems in holding work piece, sometime creates distortion and residual stresses .

The surface finish of the work pieces are affected and require further process to remove the effects. To overcome these problems substantial effort has been devoted in developing & perfecting material removal process that replace conventional machining. Non traditional machining process is one designation for this diverse family of unconventional processes, which are generally non mechanical & do not produce chips or lay pattern on the surface.

PRINCIPLE OF WIRE CUT EDM MACHINE

A series of electrical pulses generated by the pulse generator unit is applied between the work piece and the traveling wire electrode. In the event of spark discharge, there is a flow of current across the wire electrode and work piece gap. Energy contained in a tiny spark discharge removes a fraction of work piece material. Large number of such time spaced tiny discharges between the work piece and wire electrode causes the electro erosion of work piece material.

The figure 2 and 3 shows the sparking cycles and the electrical pulse at the electrode gap.

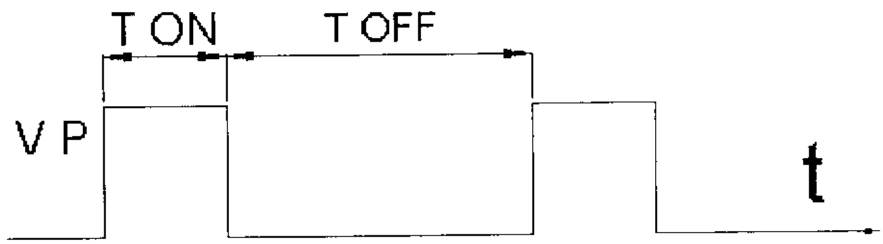


Figure 3 Graphical Representation of Sparking Cycles

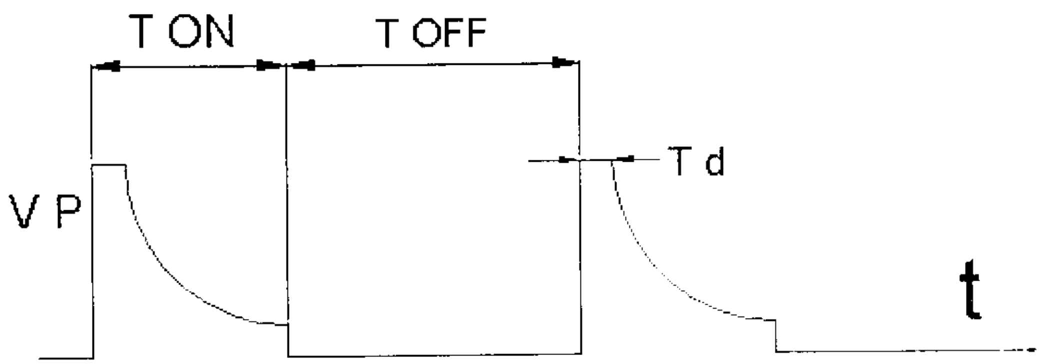


Figure 4 Series of Electrical pulse at the electrode gap

T_{ON}	:	Pulse ON period
T d	:	Spark initiation period
T_{OFF}	:	Pulse OFF period
T_P	:	Spark initiation period
V_P	:	Open gap voltage

MACHINE TOOL :

The machine tool comprises of a main work table (called as X-Y table), an auxiliary table (called as U-V table) and a wire drive mechanism. The work piece is mounted and clamped on the main work table. A schematic diagram of wire cut EDM unit is shown in figure 5. The machine model in which experiment carried out is ELEKTRA SPRINTCUT -734

The main table moves along X and Y axes, in steps of 1 micron, by means of servo motors, and also the U-V table moves, in steps of 1 micron, by means of servo motors. U & V axes are parallel to X & Y axes respectively.

A traveling wire, which is continuously fed from wire feed spool, is caused to travel through the work piece and goes finally to the waste-wire box. Along its traveling path, the wire is supported under tension, between a pair of wire guides which are disposed on both (lower and upper) sides of the work piece. Lower wire guide is stationary whereas the upper wire guide is supported by the U-V table.

The upper wire guide can be displaced transversely, along U-V axis, with respect to the lower wire guide. It can also be positioned vertically along Z-axis by moving the vertical arm.

As the material removal or machining proceeds, the worktable carrying the work piece is displaced transversely along a predetermined path, which is stored in the controller. The path specifications (path program) can be supplied to the controller through RS 232 C port of floppy diskette from the part programming system or directly through the controller keyboard.

When the X-Y table is moving along the predetermined path while the U-V table is kept stationary, a straight cut with a predetermined pattern is formed.

CONCEPT OF WIRECUT EDM

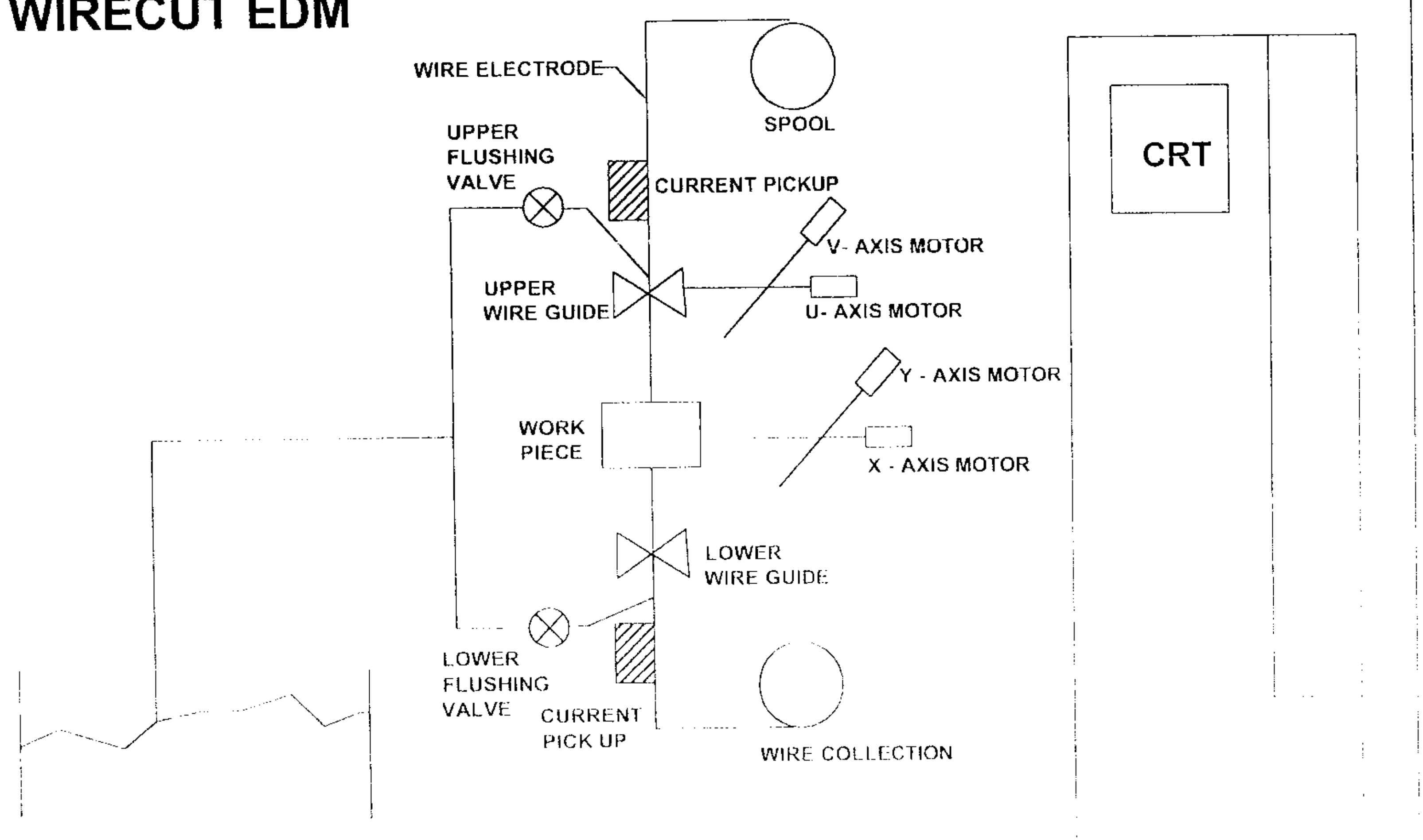


Figure 5 Wire cut EDM Machine Tool

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.

Power Supply

The power supply unit comprises of electric pulse generator, motor driver units of X, Y, U, V axes and controller.

Dielectric Supply

While the machining is continued, the machining zone is continuously flushed with water passing through the nozzles on both sides of the work piece. The spark discharge across the work piece and wire electrodes causes ionization of the water, which is used as a dielectric medium.

It is important to note that ionization of water leads to the increase in water conductivity. An ion exchange resin is used in dielectric distribution system, in order to prevent the increase in conductivity and to maintain the conductivity of the water constant.

Part Programming

The geometry of the profile and the motion of the wire-electrode tool along the profile are fed to the part programming system using keyboard. The profile geometry is defined in terms of various geometrical definitions of point, line and circle as the wire-tool path elements on graphical screen, by using a totally menu driven software. The wire compensation (for wire diameter and machining over cuts) and taper angle can be specified for the total path or for each path element separately. After the profile is fed to the computer, all the numerical information about the path is calculated automatically and its printout is generated. The entered profile can be verified on the graphic display screen and corrected, if necessary. After successful profile definition, the profile is recorded by the computer on a floppy disc which can be used in the controller for the execution.

Work Piece Material

Any slight dislocation in the work piece material may result in distorted job. It is important to use the material free from residual stresses, arising from various processes. This may affect the machining accuracies to a very large extent.

Work piece material should be

- Electrically conductive (at least 0.1 micro-ohm/cm)
- Suitable for clamping.
- Non-combustible.
- Nonviolent chemical reactions with water, Oxygen, Hydrogen.

Wire Electrode :

The wire electrode is generally brass wire coated with zinc. The other materials are copper, molybdenum & tungsten.

Copper have low tensile strength high melting point which was used in earlier version of machine. Copper & brass wire are suitable for machining thick work pieces and cuttings speed is also high.

For high precision jobs molybdenum and tungsten wire are used ranging from diameter 0.001"to 0.0011". These wires are for suitable for larger thickness of cutting speed is slow. For higher cutting speeds large diameter wire are used. The wire electrode should have a sufficient tensile strength and should be of uniform diameter and free from kink and twist

Specifications:

Machine Model: ELEKTRA SPRINTCUT – 734

Table 2: Specifications

S NO	TRAVEL RANGE	AXIS	
1	LONGITITUDINAL	Y	400 MM
		V	+/- 40 MM
2	LATERAL	X	300 MM
		U	+/- 40 MM
		Z	225MM
3	MAXIMUM WORK PIECE SIZE	400 x 500 x 200	
4	MAXIMUM WORK PIECE WEIGHT	400 KG	
5	DIAMETER OF ELECTRODE	0.25 DIA STD	

Applications and Limitations:

Profiles of any complex shapes can be machined by using wire cut EDM m/c. Process is widely used for the manufacture of punches, dies & stripper plates with modern machines capable of cutting die relief, intricate opening, tight radius, contours. The process is applicable to all type of materials that are fairly good electrical conductors including metals, allcys and most carbides. The melting point, hardness, and brightness of the material impose no limitations. EDM provides a relatively simple method for making holes of cross sections in material, that are hard or brittle to be machined by other methods. The forces between the tool and work piece is virtually zero, very delicate work can be done. The process leaves no burs on the edges.

Machining Parameters :

There are about 10 machining parameters in the wire cut EDM machine and some are discussed here.

1. Pulse on time : T_{ON}

During this period the voltage is applied across the electrodes, higher the T_{ON} setting larger is the pulse on period. The single pulse discharge energy increases with increasing T_{ON} Period, resulting in higher cutting rate. With higher values of T_{ON} surface roughness tends to be higher.

2. Pulse off time : T_{OFF}

Voltage for the gap is absent during this period, with a lower value of T_{OFF} there are more number of discharges in a given time, resulting in increase in the sparking efficiency. As a result the cutting rate also increases.

3. Peak current : I_P

The current applied across the electrodes is peak current. Increase in the peak current value will increase the pulse discharge energy, which in turn can improve the cutting rates

4. Flushing pressure of dielectric water: F_P

In order to increase the conductivity and anyway carbon particles water is to supplied through nozzles. Flushing pressure is an important parameter, high input pressure of dielectric is necessary for cutting with higher values of pulse power and also while cutting the jobs of higher thickness low input pressure is used for this jobs.

5. Wire feed rate: W_R

Wire feed rate is at which the brass wire is fed for sparking.

6. Wire tension setting: W_T

This is a gram equivalent load with which the continuously fed wire is kept under tension so that it remains straight between the wire guides. While the wire is being feed continuously, appropriate wire tension avoids this intentional wire deflection from its straight path between the wire guides. The wire deflection is caused due to spark induced reaction forces and water pressure.

7. Radius compensation factor: CR_K

This is the amount of corner correction for 1mm corner radius. From this value, corner correction of other corner is automatically done by controller. CRK value depends on job material and thickness.

8. Die electric fluid Rate: F_R

The value at which the die electric water is supplied to the sparking zone.

9. Servo feed setting: SR

This parameter decides the servo speed; the servo speed can vary with gap voltage. It can be held constant while machining.

10. Corner control : C_C

This factor is concerned with machine tool to control corner radius and is controlled by machine.

EDM have advantage of machining hard, high strength & temperature resistant materials, which is very difficult to cut using conventional machining techniques like milling, turning etc. Mechanical deformation is a common problem in conventional machining process such as cutting. This problem of the micron level is serious. Since there is no mechanical tool contact in most of non-traditional machining process, they have a better edge in micro machining field.

PROBLEM DESCRIPTION

PROBLEM DESCRIPTION

INTRODUCTION

The wire cut EDM Process is used to cut the die plates and other parts of a press tools & mould bases. The important criteria in machining the parts of press tools & mould bases are accuracy & better surface finish. Better accuracy is obtained from EDM process as a CNC controller controls the machine tool.

Due to spark erosion process the surface finish of the components are affected. Another point to be noted during the EDM process is cutting speed; the operating cost of the machine is very high. It will be economical for us if the jobs are machined in shorter period and productivity will also be high.

Objective of The Project

The objective of the project is to abtain minimum surface roughness of the parts machined by EDM machine and maximum cutting speed of Wire cut EDM machine. An attempt is made to analyze the surface roughness along with cutting speed under different combinations of parameters. It is difficult to find the different parametric combinations for variety of jobs as the EDM process is controlled by more than ten machining parameters.

Methodology

The machining parameters should be optimized to get better result. The methodology adopted to carry out the project is by Taguchi's Design of experiments Technique. Dr.Genichi Taguchi has suggested a new approach for design of experiments, which identifies the nature of parameters by conducting minimum no of experiments and which is extensively applicable in manufacturing industries.

Taguchi method is a powerful experimental technique easy to apply for improving the quality of manufactured products. Design of experiments using Taguchi approach will give clear idea about the most influencing parameters on surface roughness & cutting speed with less no of experiments.

The work piece selected for carrying the experiment is steel OHNS & Copper; separate experiments are done for steel & copper plate. Initially a hole is drilled on the 30 mm thick steel plate and copper plate to insert the wire. The steel plates are hardened & cleaned before machining. The hardness of the work piece material is 50Rc. A brass wire of 0.25 mm diameter is used to cut the material.

The experiment to be carried is planned according to the procedure suggested by Dr. Taguchi. The parameters affecting the quality characteristics are short-listed. The parameters are considered as factors. About 7 factors are considered and two levels were fixed for each factor. An L8 0A table has been selected.

The experiment is executed & response namely surface roughness& cutting speed values are noted. Software called Qualitek-4 has been used for analyzing the experiment & obtains results. In initial stage of the experiment the noise factors & interaction among the factors are not considered.

METHODOLOGY

METHODOLOGY

5.1 DESIGN OF EXPERIMENT: -

Design of experiment is simultaneous evaluation of two or more factors for their ability to affect the resultant average or variability of particular product or process characteristics. To accomplish this in an effective and statistically proper fashion, the levels of the factors are varied in a strategic manner, the results of the particular test combinations are observed and the complete set of results is analyzed to determine the influential factors & preferred levels.

Design of Experiments Process:

The DOE process is divided into 3 main phases the 3 phases are

a. **Planning phase**
b. **Conducting Phase**
c. **Analysis Phase**

The steps Involved in DOE Process is

a. Planning Phase

1. State the problem or area of concern.
2. State the objective of the experiment.
3. Select the quality characteristics & measurement system.
4. Select the factors that may influence the selected Quality Characteristics.
5. Identify Control & noise factors.
6. Select levels for the factors.
7. Select the appropriate orthogonal array.
8. Assign factors to orthogonal array.

b. Conducting Phase

9. Conduct test described by trials in OA.

c. **Analysis phases.**

10. Analyze and interpret results of the experimental trials.

11. Conduct Confirmation experiment.

Step by step procedure of DOE Process is discussed below.

PLANNING PHASE

1. State the problem of area of concern:

Surface roughness is considered to be crucial in the most of cases. The surface roughness is corrected by means of manual operations to the detriment of the precision and the production times and costs. The surface finish of wire cut EDM process has improved significantly in recent years with advent of new technology. However parts machined by EDM process remain heavily stepped and are considered unacceptable for many secondary applications without some degree of manual finishing.

If we are able to arrive at a minimum Ra value, the time spent on the final surface finishing process like lapping can be reduced. Some degree of allowance has to be kept for surface finishing process to maintain the accuracy levels

The problem is concerned with obtaining minimum surface roughness on the work pieces machined by wire cut EDM process. Optimizing the machining parameters of the machine attains the above objective. If the surface quality is poor the machined parts may get rejected.

The Cost of operating the EDM Machine is very high. It will create a big loss for the company. Again the productivity can be increased if the cutting speed is maximized so we have to find optimum level of parameters. which will give minimum surface finish & maximize the cutting speed.

Loss due to slow cutting speed.

Cost of separating Machine = Rs. 300/hour

If the cutting speed is 3.5 mm/ min.

The machine is able to 100 mm by 28 minutes

If the cutting speed in 4 mm /min.

The machine is able to cut 100 mm by 22 minutes.

Time saved = 28-22

= 6 minutes.

We are able to save a sum of Rs.30/hour by maximizing cutting speed.

2. State the objective of the Experiment :-

a. Improve the surface finish of the machined parts.
b. Eliminate trial & error method of setting machining parameters.
c. Optimizing the machining parameters & response
d. Maximize the cutting speed of machine.

This step is also concerned with determining the process parameters which affect the surface roughness & cutting speed. From studying the wire cut EDM process there are about 10 machining parameters they are listed below.

The machining parameters are

1. Pulse on time
2. Pulse off time
3. Wire feed rate
4. Wire tension
5. Die electric fluid flow rate
6. Dielectric flow pressure.
7. Peak current
8. Corner control
9. Corner radius Compensation.
10. Servo feed setting.

3. Select quality Characteristics & measurement systems.

Quality characteristics is where the quality problem occurs from the objective of the experiment it is clear that the quality characteristics are surface Roughness Ra & cutting speed Vc. The Surface roughness is measured using a surface roughness measuring instrument. The cutting speed is noted directly form the LED display in the machine.

The selected quality characteristics are shown in the table 3

Table 3 Quality Characteristics

S.No.	Name	Denoted by	Units
1	Surface Roughness	Ra	micron
2	cutting speed	VC	Mm/min

4.Select the factors that influence the selected quality characteristics.

This is the most important step of DOE process. If the important factors are left out of the experiment, the information gained from the experiment will not be in a positive sense. It will be the information about which factors do not make a difference in the quality characteristics and other factors also to be investigated. A recommended strategy is to focus on the real problem and begin an investigation with many factors rather than just a few.

Among all parameters involved in the process some of the parameters have more effect on the response & some have least effect on the response. The selection of factors are done by conducting a discussion with the technical experts & with shop floor personnel's.

About ten machining parameters are studied & they are

1. Pulse on time
2. Pulse off time
3. Wire feed rate
4. Wire tension
5. Die electric fluid flow rate
6. Dielectric flow pressure.
7. Peak current
8. Corner control
9. Corner radius Compensation.
10. Servo feed setting.

In the parameters listed above about 7 parameters are found to be affecting the quality characteristics . The factors are

1. Pulse on time
2. Pulse off time
3. Wire feed rate
4. Wire tension
5. Die electric fluid flow rate
6. Dielectric flow pressure.
7. Peak current

Table 4 Selected Factors for Experiment

S.No	FACTORS	SYMBOL	UNITS
1	PULSE ON TIME	T_{ON}	μS
2	PULSE OFF TIME	T_{OFF}	μS
3	PEAK CURRENT	I_P	Amps
4	WIRE TENSION	W_T	Grams
5	WIRE FEED	W_F	mm/min
6	FLUID RATE	F_I	Lpm
7	FLUID PRESSURE	W_P	Kgf/cm2

The other factors are concerned with the control of the machine tool. The factors affecting the quality characteristics are listed in table 4. The machining parameters are considered as factor in the DOE process

5. Identify control & noise factors:-

Control factors:

Control factors are those parameters that can be controlled during the machining parameters. The parameters listed in the above step can be controlled though out the experiment.

Noise factors:

Noise factors are those things that a manufacturer cannot on wishes not to control for cost reasons. Noise factors can be temporally controlled during an experiment Noise factors are expensive & impossible to control in a continual basis, the focus of the experiment should be on the effects of the true control factors.

The wire cut EDM machine is operated under a controlled environment and noise factors are not considered in this experiment.

6. Selection of levels for the factors:-

A minimum of two levels are required to evaluate a factors effect on a given quality characteristics. If several factors are under consideration it is recommended to use two levels to keep the size of experiment to a minimum.

The selection of levels for factors depends on type of system or process. It decides the number of experiments to be conducted. The EDM process is more sensitive to the variation; the levels were limited to two and as advised by the experts. In addition to the above fixing of levels should have consistency while experimentation.

The cost incurred during the experiment is more so minimum number of experiments should be conducted. By referring the manuals it is advisable to fix only two levels instead of more levels. The list of the factors & levels are shown below.

Factors and levels selected for steel plate :

Table 5 Levels for Steel Plate

S.No	FACTORS	LEVEL 1	LEVEL 2
1	PULSE ON TIME	120	130
2	PULSE OFF TIME	40	48
3	PEAK CURRENT	230	250
4	WIRE TENSION	600	800
5	WIRE FEED	4	8
6	FLUID RATE	8	10
7	FLUID PRESSURE	10	15

Factors and levels selected for Copper plate :

Table 6 Levels for copper plate

S.No	FACTORS	LEVEL 1	LEVEL 2
1	PULSE ON TIME	120	130
2	PULSE OFF TIME	40	45
3	PEAK CURRENT	220	230
4	WIRE TENSION	600	800
5	WIRE FEED	3	5
6	FLUID RATE	5	7
7	Fluid PRESSURE	3	5

7. Selection of Appropriate Orthogonal arrays

Orthogonal array is a table, which provides the combinations of parameters and their levels within which the experiment is to be conducted.

The selection of orthogonal array depends upon the number of parameters & their levels.

Number of parameters are seven namely

1. Pulse ON time
2. Pulse off time
3. Peak Current
4. Wire Tension
5. Wire feed
6. Fluid Rate
7. Fluid Pressure

Number of levels : 2 namely

1. Min level
2. Max level.

L8 Orthogonal array

Table 7 L8 Orthogonal Array

S.No	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1
2	1	1	1	1	2	2	2
3	1	1	2	2	1	1	2
4	1	1	2	2	2	2	1
5	2	2	1	2	1	2	1
6	2	2	1	2	2	1	2
7	2	2	2	1	1	2	2
8	2	2	2	1	2	1	1

According to number of parameters & levels L8 Orthogonal array table is selected. The L8 Orthogonal array is shown in table 7

8. Assign factors to Orthogonal Array :

With the seven factors the recommended choice is to use L8 OA to maintain a small experiment for the beginning round. The seven factors are assigned to the seven column in the orthogonal array table. The below table shows L8 OA with factors assigned. Since there are seven factors and seven columns in an L8 Orthogonal Array.

The factor assignment is not necessary, each factor is assigned to each column. The particular column to which a factor is assigned is not important since all the combinations column assignments will be statistically equivalent.

The table 8 shows the factors assigned to the column and the level in terms of original values

Orthogonal array for steel plate :

Table 8 Orthogonal Array For Steel Plate

S.No	1	2	3	4	5	6	7
	T_{ON}	T_{OFF}	I_P	W_T	W_F	F_R	F_P
1	120	40	230	600	4	8	10
2	120	40	230	600	8	10	15
3	120	48	250	800	4	8	15
4	120	48	250	800	8	10	10
5	130	40	250	800	4	10	10
6	130	40	250	800	8	8	15
7	130	48	230	600	4	10	15
8	130	48	230	600	8	8	10

Orthogonal array for copper plate :

Table 9 Orthogonal Array for Copper Plate

S.No	1 T_{ON}	2 T_{OFF}	3 I_P	4 W_T	5 W_F	6 F_R	7 F_P
1	120	40	220	600	3	5	3
2	120	40	220	600	5	7	5
3	120	45	230	900	3	5	5
4	120	45	230	900	5	7	3
5	130	40	230	900	3	7	3
6	130	40	230	900	5	5	5
7	130	45	220	600	3	7	5
8	130	45	220	600	5	5	3

CONDUCTING PHASE

9. Conducting test described by trials in OA:-

After planning phase has completed & conducting phase is started. The experiment is conducted in random fashion & one trial for each experiment. An L8 OA with one trial per test makes the experiments 90% sure of detecting a change in average of approximately 2.4 standard deviation. The responses are noted down is the response column.

A separate sheet should be constructed for each of eight experiments to avoid any confusion as to what combination of factors & levels will be used in any given trial.

The combination of factors for trial 2 for experiment on steel plate is given below in table 10

Table 10 Trial Sheet for Experiment no 2 for Ra steel plate

S. No	T_{ON}	T_{OFF}	I_P	W_T	W_F	F_R	F_P	Response
1	120	48	230	800	8	10	5	R_1

The parameter 1, 2, 3 fixed to min level & parameters 4 to 7 is fixed to max level. The experiments are conducted for both the responses surface roughness & cutting speed, according to the trial conditions specified by the qualitek software. The results table corresponding to experiment is shown below

Results table for Surface roughness and cutting speed for steel plate :

Table 11 Results for Steel Plate Experiment

S.No	1	2	3	4	5	6	7	R_a micron	V_C Mm/min
	T_{ON}	T_{OFF}	I_P	W_T	W_F	F_R	F_P		
1	120	40	230	600	4	8	10	2.5	3
2	120	40	230	600	8	10	15	2.3	2.9
3	120	48	250	800	4	8	15	2.25	2.6
4	120	48	250	800	8	10	10	2.4	2.5
5	130	40	250	800	4	10	10	2.7	3.2
6	130	40	250	800	8	8	15	2.8	3.3
7	130	48	230	600	4	10	15	2.3	2.8
8	130	48	230	600	8	8	10	2.2	2.7

Results table for Surface roughness and cutting speed for copper plate

Table 12 Results for Steel Plate Experiment

S.No	1 T_{ON}	2 T_{OFF}	3 I_P	4 W_T	5 W_F	6 F_R	7 F_P	R_a micron	V_C Mm/min
1	120	40	220	600	3	5	3	3.6	4.9
2	120	40	220	600	5	7	5	3.4	4.8
3	120	45	230	900	3	5	5	3.3	4.5
4	120	45	230	900	5	7	3	3.5	4.6
5	130	40	230	900	3	7	3	3.8	4.3
6	130	40	230	900	5	5	5	3.9	4.4
7	130	45	220	600	3	7	5	3.4	4.7
8	130	45	220	600	5	5	3	3.2	4.5

ANALYSIS PHASE

10. Analysis and interpretation of results

The final phase of DOE process is analysis and interpretation of results. The analysis is done by using Qualitek-4 software. The input for the software is fed in terms of factors and levels. The experimental results are entered in the results column. The software provides the graph regarding main effects of parameters on the response. The software itself also constructs the ANOVA table. The results obtained from the software are discussed below.

QUALITEK – 4:

QUALITEK – 4 is specialized software used to solve the Taguchi's design of experiment problems. The software is designed and developed by R.K.Roy, PhD and licensed to NUTEK Inc., USA.

The preliminary step in using the software is specifying the number of levels and factors. Based on that orthogonal array is selected. The user can specify the particular orthogonal array. The various arrays available are

2 LEVEL ARRAY L4, L8, L16, L32, L54, L64
3 LEVEL ARRAY L9, L15, L27, L81

The factors and the levels are entered in a separate column and results against the results column

The experiment is conducted in a random order given by the software. In the analysis part the software generates the graph regarding main effects and interactions, the factors most influencing the response. The software generates the ANOVA table and also it gives the optimum conditions of the parameters. The software finds wide applications in various corners of the industries where design parameters need to be optimized

ANALYSIS FOR SURFACE ROUGHNESS AND CUTTING SPEED FOR STEEL PLATE

Analysis for Surface Roughness

1. Selection of inner array for experiment design

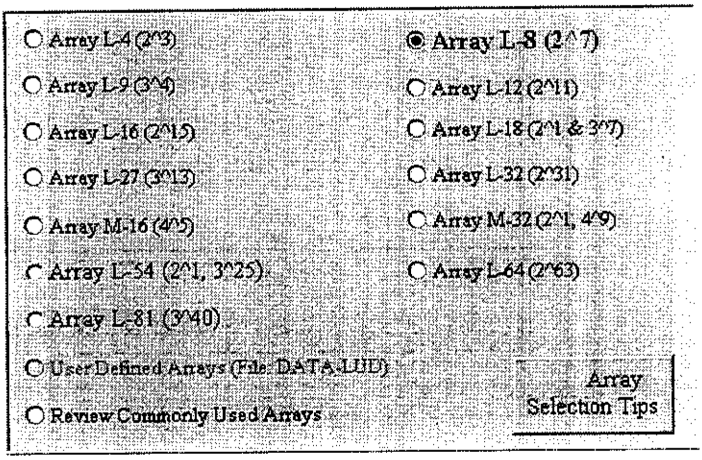


Figure 6 Array Design Menu

An L8 Orthogonal array is selected from the menu

2. Enter Factors and Levels

	Factors	Level 1	Level 2
1	TON	120	130
2	TOFF	40	48
3	IP	230	250
4	WT	600	800
5	WF	4	8
6	FR	8	10
7	FP	10	15

Figure 7 Factors and levels

The factors and levels for the experiment are entered in the column

3. Random order of running experiments

The random order of conducting the experiment is generated by the software and the order is Experiment No. 6, 4, 5, 2, 7, 3, 8, and 1

4. Enter results:

Table 13 Results

	Sample# 1
Trial# 1	2.5
Trial# 2	2.3
Trial# 3	2.25
Trial# 4	2.4
Trial# 5	2.7
Trial# 6	2.8
Trial# 7	2.3
Trial# 8	2.2

The experimental results are in the column for analysis

5. Quality characteristics:

The quality characteristics are used find the optimum conditions of the parameters. For minimum surface roughness value the quality characteristics selected is **Smaller the better**

6. Results range graph :

In order to know the variation of the observed response, the observed data is transformed in to a graphical form. The results lie between 2 to 3 microns
The figure show the range the graph

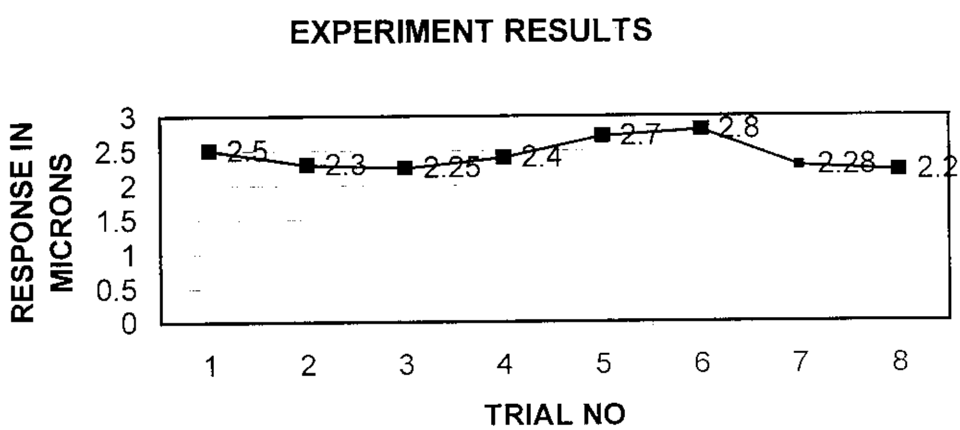


Figure 8 Ra Steel plate

7. Main effects graph Surface roughness for steel plate

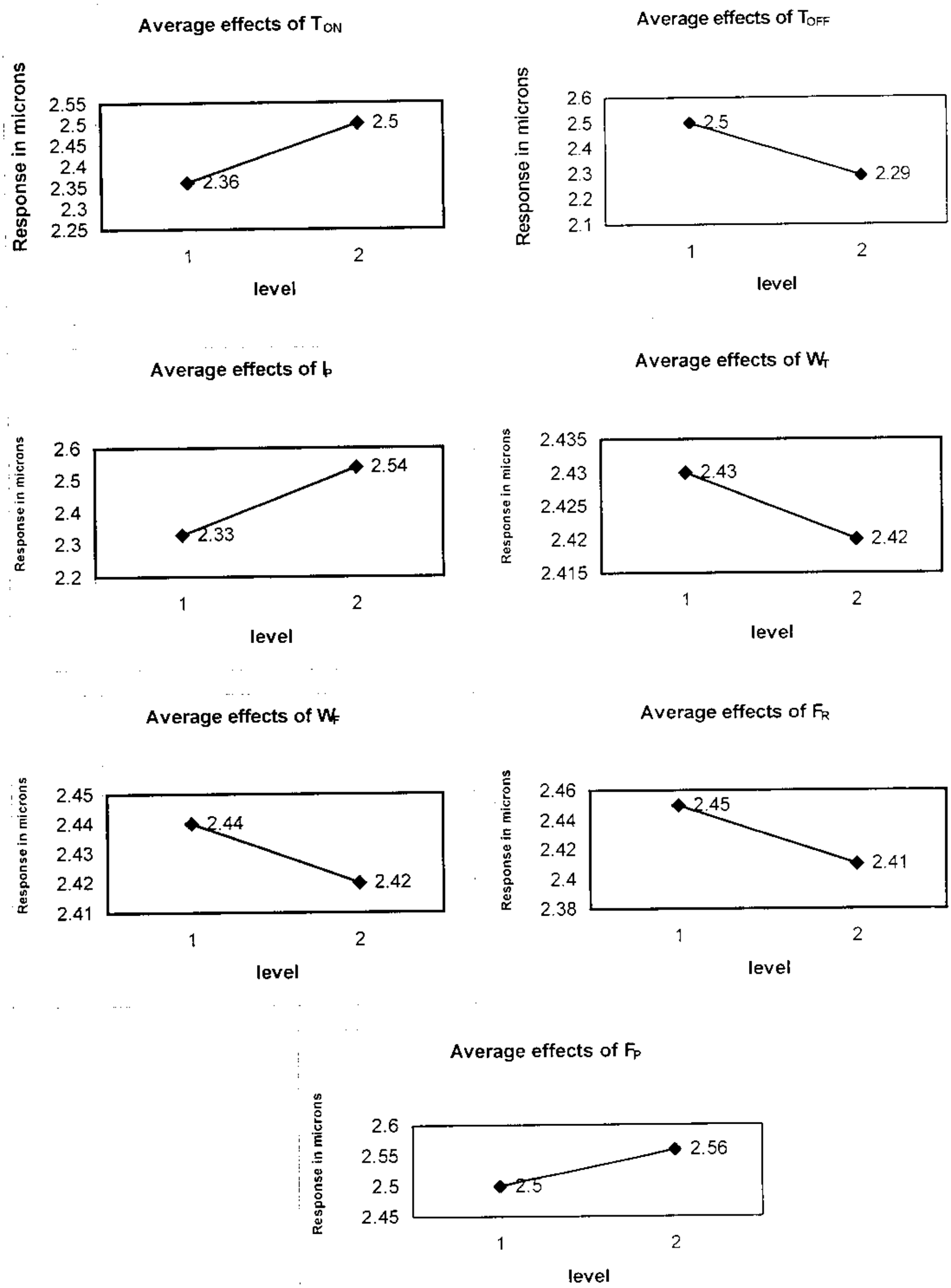


Figure 9 Main effects for Ra Steel plate

8. ANOVA Table :

Table 14 ANOVA for Ra Steel plate

S NO	*FACTOR*	*DOF*	SUM OF SQUARES	VARIANCE	% CONTRIBUTION
1	T_{ON}	1	0.037	0.037	11.295
2	T_{OFF}	1	0.165	0.165	49.377
3	I_P	1	0.09	0.09	26.976
4	W_T	1	0.00031	0.00031	0.092
5	W_F	1	0.00031	0.00031	0.092
6	F_T	1	0.0028	0.0028	0.841
7	F_P	1	0.037	0.037	11.293
8	TOTAL	7	0.3344		100

When all the column of orthogonal array is assigned the error variance cannot be calculated. But the error variance can be calculated by combining the factors, which have small sum of squares. Some factors taken for an experiment, latter will not be significant even through considered before. The combined factors are considered as error variance.

In an L8 orthogonal array the total sum of squares is equal to the sum of squares of all the factors. If there is any unassigned column is equal to error sum of squares.

The pooling up strategy entails F-testing the smallest column effect against the next larger to see if significance exists. If no significance exists, then two effects are pooled together to the next larger column effect until some significant F-ratio exists

9. Pooled ANOVA table :

Table 15 Pooled ANOVA Table Ra Steel Plate

S NO	FACTOR	DOF	SUM OF SQUARES	VARIANCE	F- RATIO	% CONTRIBUTION
1	T_{ON}	1	0.037	0.037	32.991	10.978
2	T_{OFF}	1	0.165	0.165	144.223	49.151
3	I_P	1	0.09	0.09	78.794	26.697
4	F_P	1	0.037	0.037	32.991	10.977
5	ERROR	3	0.00342	0.00342		2.197
6	TOTAL	7	0.334			100

After pooling it is found that there is a slight difference in the percentage influence of factors. To increase the statistical significance of important factors, the factors with small variances should be pooled .

The graph in figure shows the significant factors

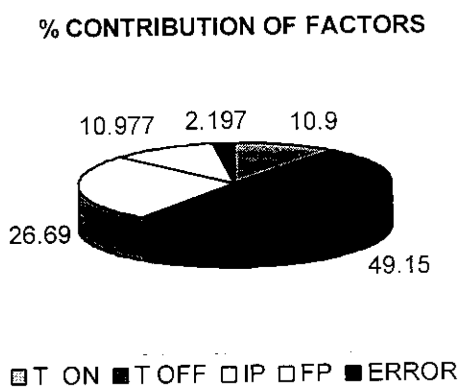


Figure 10 Ra steel plate

The factors wire tension; wire feed and fluid rate are combined together. The factors are pooled together. There is a significance exists by conducting F - ratio test at 90% confidence limit. The factors contribution is less when compared to the normal ANOVA table

10. Optimum Conditions and performance:

The optimum conditions are given below

Table 16 Optimum Conditions Ra for Steel plate

S.No	FACTORS	LEVEL	LEVEL DESCRIPTION
1	T_{ON}	1	120
2	T_{OFF}	2	48
3	I_P	1	230
4	W_T	2	800
5	W_F	2	8
6	F_T	2	10
7	W_P	2	15

Expected result at optimum condition : 2.009 microns

11. Interaction graph :

The interaction graph are studied for the factors which have greater influence on the response. There is an interaction between the factors Ton and T_{OFF} the other factors have no interactions. The graphs are shown in figure 11

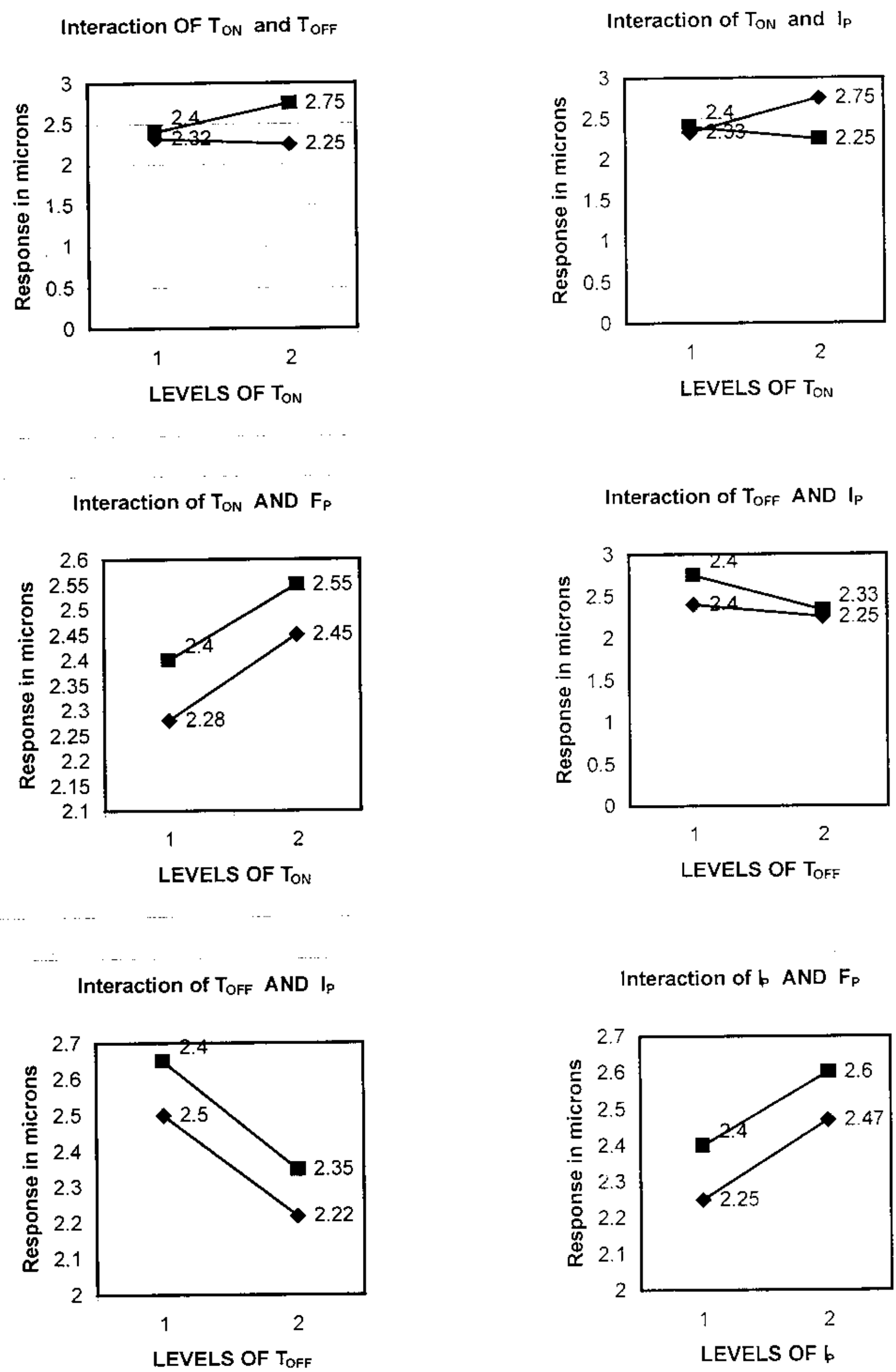


Figure 11 Interaction graph for Ra Steel plate

ANALYSIS FOR CUTTING SPEED

The same procedure is done for analyzing the cutting speed for steel plate. The results are entered in the results column

1.Experimental results :

Table 17 Results for Vc Steel Plate

EXPERIMENT NO	Ra
1	3
2	2.9
3	2.6
4	2.5
5	3.2
6	3.3
7	2.8
8	2.7

2.Quality characteristics :

The cutting speed should be maximum so the Bigger the Better is selected

3 . Result range graph :

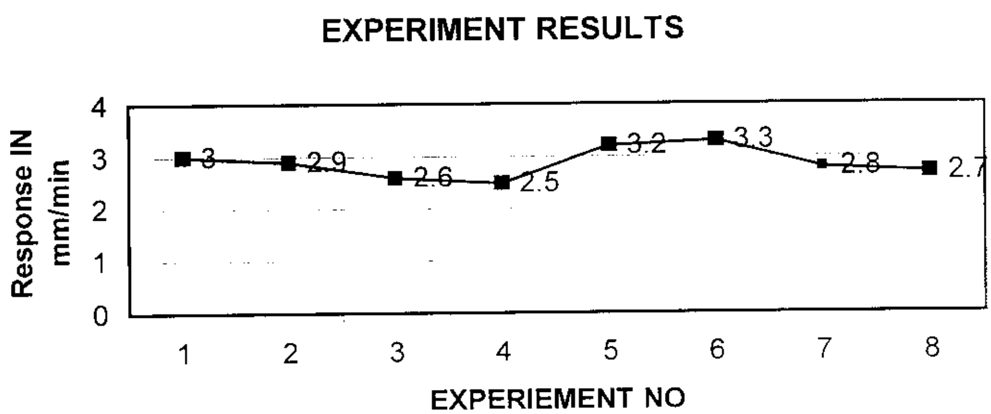


Figure 12 Range for Vc Steel plate

4. Main effects graph :

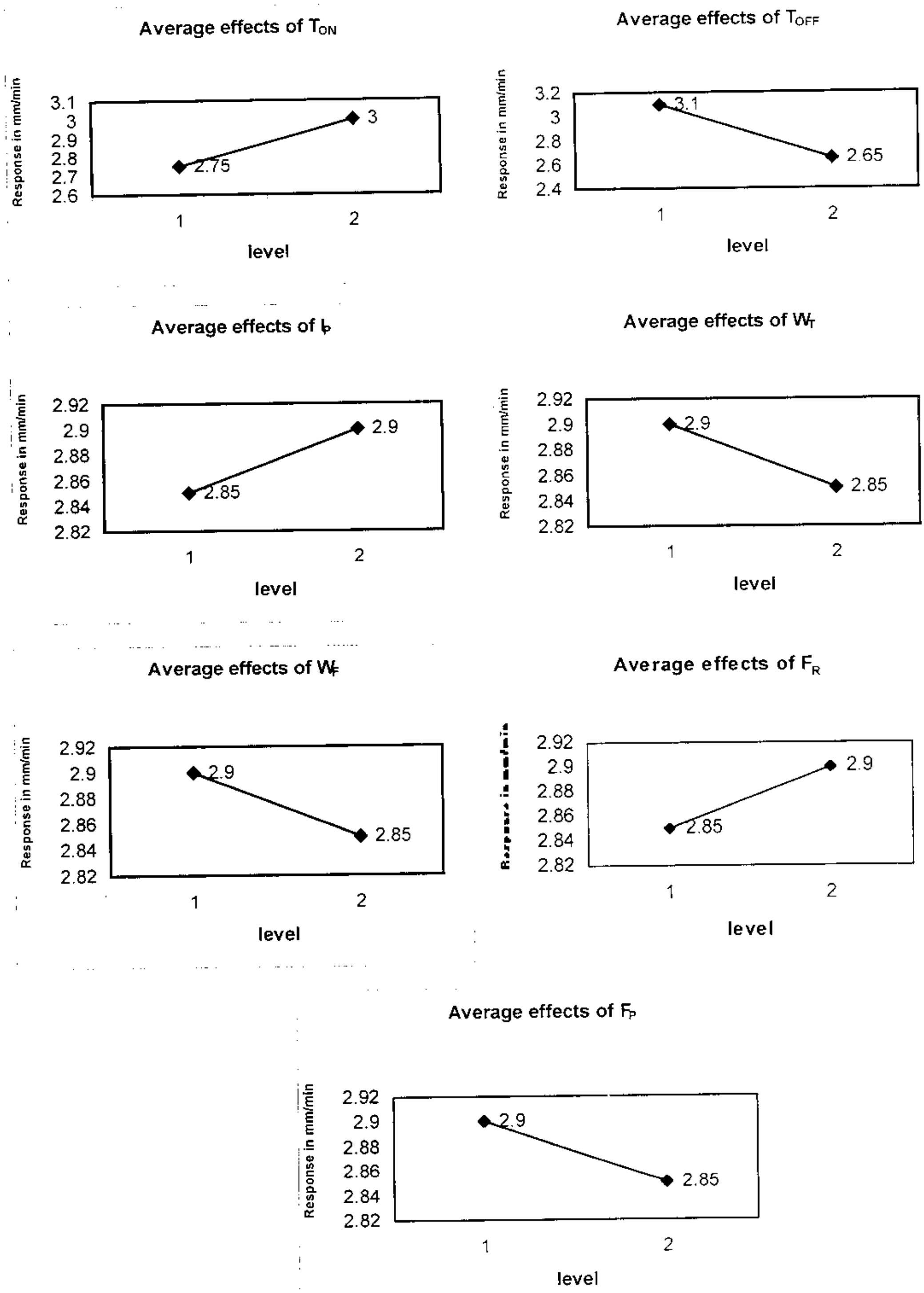


Figure 13 Main effects Vc Steel plate

5. ANOVA Table :

Table 18 ANOVA Table Vc Steel Plate

S NO	FACTOR	DOF	SUM OF SQUARES	VARIANCE	% CONTRIBUTION
1	T_{ON}	1	0.125	0.125	22.518
2	T_{OFF}	1	0.405	0.405	72.97
3	I_P	1	0.005	0.005	0.9
4	W_T	1	0.005	0.005	0.9
5	W_F	1	0.005	0.005	0.9
6	F_T	1	0.005	0.005	0.9
7	F_P	1	0.005	0.005	0.9
8	TOTAL	7	0.005		100

6. Pooled ANOVA :

Table 19 Poole ANOVA Table Vc Steel Plate

S NO	FACTOR	DOF	SUM OF SQUARES	VARIANCE	F-RATIO	% CONTRIBUTION
1	T_{ON}	1	0.125	0.125	24.99	21.621
2	T_{OFF}	1	0.405	0.405	80.99	72.072
3	ERROR	5	0.025	0.005		6.037
4	TOTAL	7	0.555			100

% Contribution of Factors

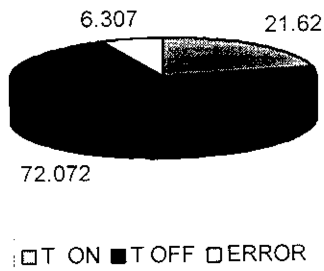


Figure 14 Vc Steel plate

The factors pulse on time and pulse off time are found to be significant and the other factors are pooled

7. Optimum Conditions and performance :

Table 20 Optimum Conditions Vc Steel Plate

S.No	FACTORS	LEVEL	LEVEL DESCRIPTION
1	T_{ON}	2	130
2	T_{OFF}	1	40
3	I_P	2	250
4	W_T	1	600
5	W_F	1	4
6	F_T	2	10
7	W_P	1	10

Expected result at optimum condition : 3.34 Mm/min

8. Interaction graph

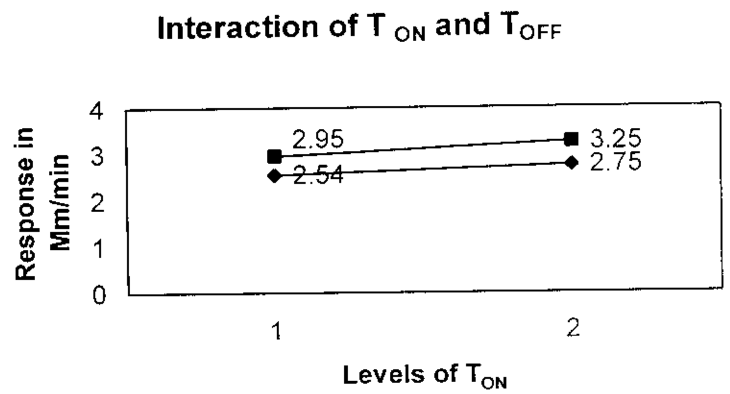


Figure 15 Interaction graph Vc steel plate

There is no interaction between the two factors

ANALYSIS FOR SURFACE ROUGHNESS AND CUTTING SPEED FOR COPPER PLATE

Analysis for Surface Roughness

The results are entered in the results column

1.Experimental results :

Table 21 Results Ra Copper plate

EXP NO	Vc
1	3.6
2	3.4
3	3.3
4	3.5
5	3.8
6	3.9
7	3.4
8	3.2

2. Quality characteristics :

Smaller the better quality characteristics for the analysis

. 3 . Result range graph :

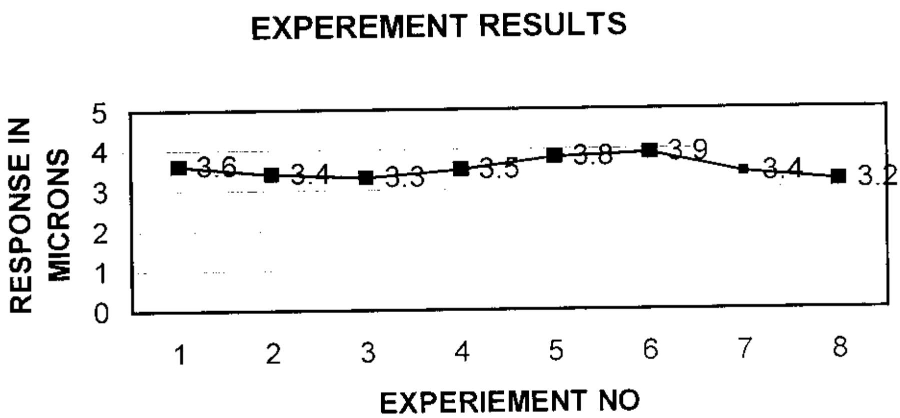
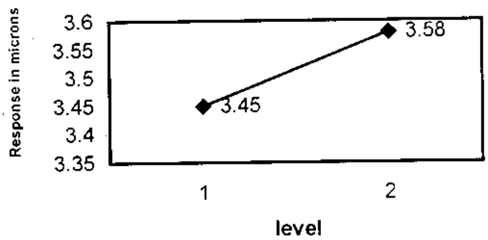


Figure 16 Range graph for Ra Copper plate

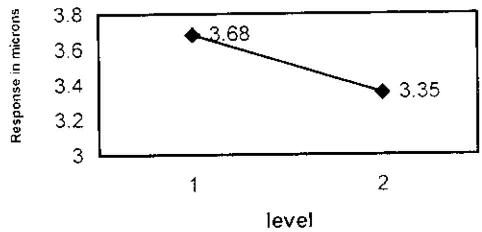
The range graph is drawn to study the variation the figure shows the range graph. The values lies between 3.9 and 3.2

4. Main effects graph

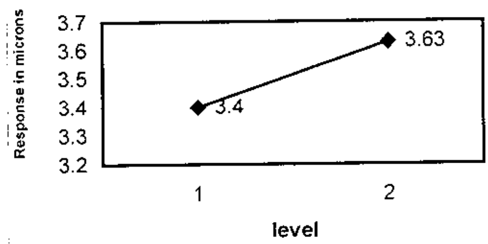
Average effects of T_{ON}



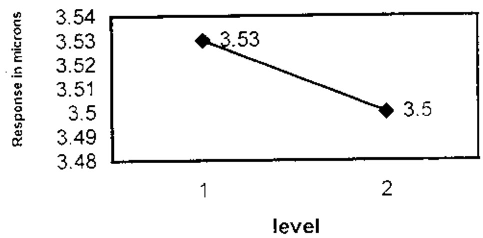
Average effects of T_{OFF}



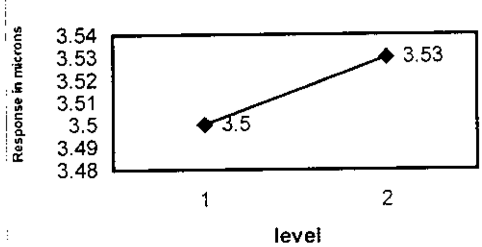
Average effects of I_P



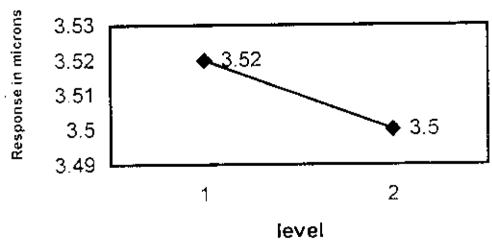
Average effects of W_T



Average effects of W_F



Average effects of F_R



Average effects of F_P

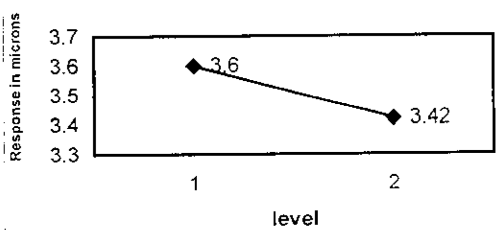


Figure 17 Main effects for Ra Copper plate

6. ANOVA Table :

Table 22 ANOVA Table for Ra Copper plate

S NO	FACTOR	DOF	SUM OF SQUARES	VARIANCE	% CONTRIBUTION
1	T_{ON}	1	0.03125	0.03125	7.645
2	T_{OFF}	1	0.21125	0.21125	51.682
3	I_P	1	0.10125	0.10125	24.77
4	W_T	1	0.00125	0.00125	0.306
5	W_F	1	0.00125	0.00125	0.306
6	F_T	1	0.00125	0.00125	0.306
7	F_P	1	0.06125	0.06125	14.984
8	TOTAL	7	0.40875		100

7. Pooled ANOVA :

Table 23 Pooled ANOVA Table Ra Copper Plate

S NO	FACTOR	DOF	SUM OF SQUARES	VARIANCE	F – RATIO	% CONTRIBUTION
1	T_{ON}	1	0.03125	0.03125	25	7.354
2	T_{OFF}	1	0.21125	0.21125	169	51.473
3	I_P	1	0.10123	0.10123	81	24.509
4	F_P	1	0.06125	0.06125	49	14.705
5	ERROR	3	0.00375	0.00125		1.959
6	TOTAL	7	0.40875			100

The factors Pulse on time, pulse off time, peak current and fluid pressure are influencing the surface roughness as for the steel plate

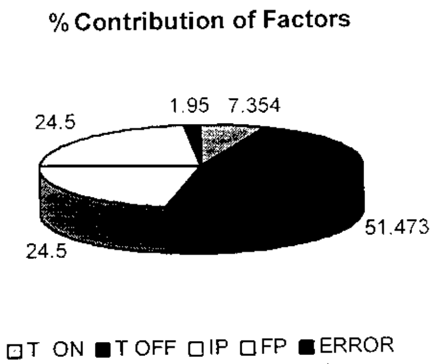


Figure 18 Ra for Copper plate

8. Optimum Conditions and performance :

Table 24 Optimum Conditions Ra Copper Plate

S.No	FACTORS	LEVEL	LEVEL DESCRIPTION
1	T_{ON}	1	120
2	T_{OFF}	2	45
3	I_P	1	250
4	W_T	2	900
5	W_F	1	3
6	F_T	2	17
7	W_P	2	5

Expected result at optimum condition : 3.046 microns

9. Interaction Graph :

The study of interaction graph of the factors influencing, the factors pulse on time and peak current are found interacting

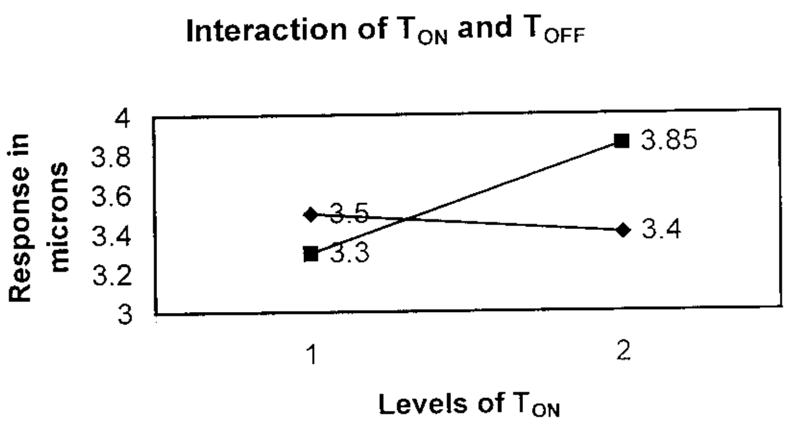


Figure 19 Interaction graph for Ra Copper plate

ANALYSIS FOR CUTTING SPEED

The results are entered in the results column

1. Quality characteristics :

Bigger the better

2. Experimental results

Table 25 Results Vc Copper Plate

EXP NO	Vc
1	4.9
2	4.8
3	4.5
4	4.6
5	4.3
6	4.4
7	4.7
8	4.5

. 3 . Result range graph :

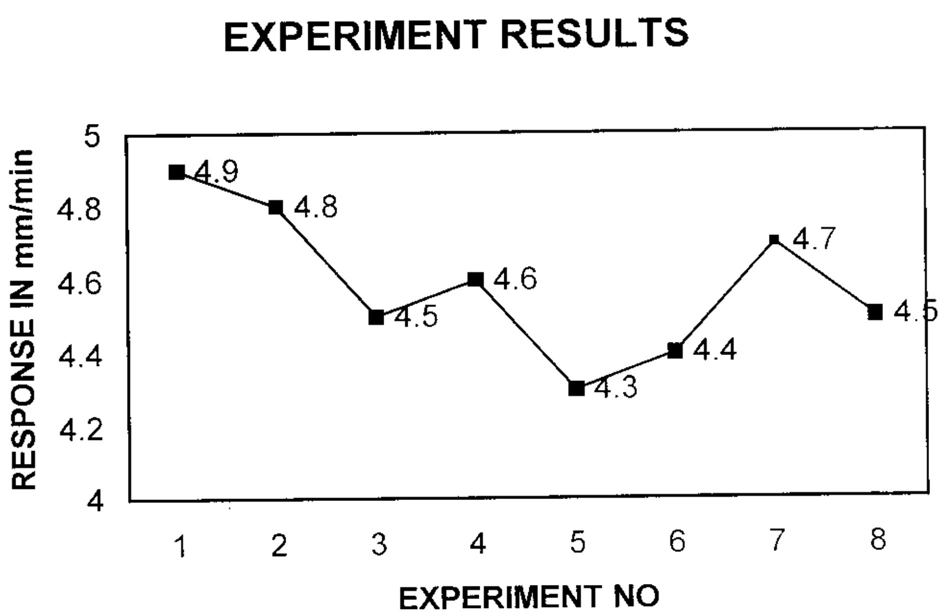


Figure 20 Range for Vc Steel plate

5. Main effects graph :

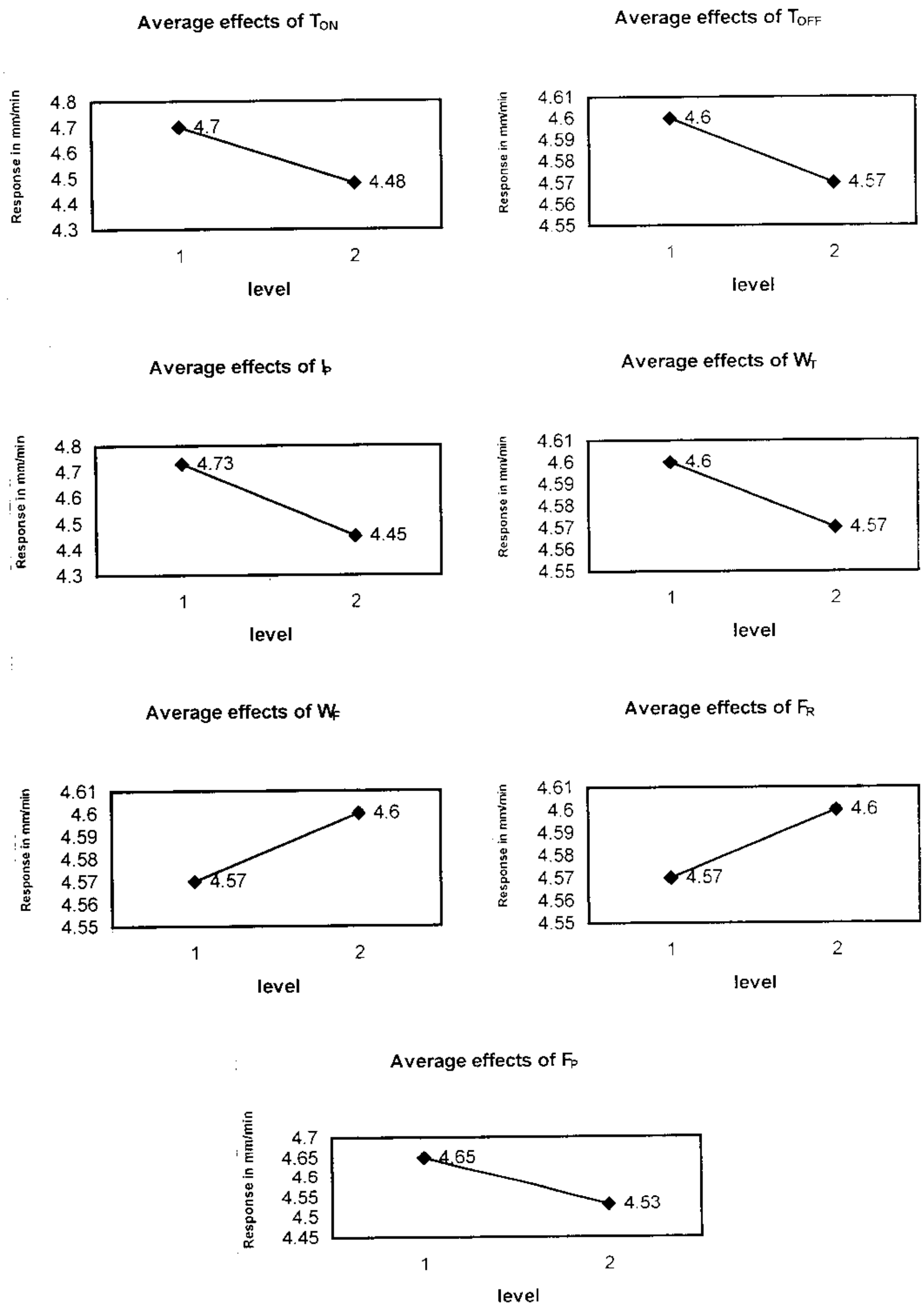


Figure 21 Main effects for Vc Copper plate

6. ANOVA Table :

Table 26 ANOVA Table Vc for Copper Plate

S NO	*FACTOR*	DOF	SUM OF SQUARES	VARIANCE	% CONTRIBUTION
1	T_{ON}	1	0.10125	0.10125	35.06
2	T_{OFF}	1	0.00125	0.00125	0.43
3	I_P	1	0.15125	0.15125	52.38
4	W_T	1	0.00125	0.00125	0.43
5	W_F	1	0.00125	0.00125	0.43
6	F_T	1	0.00125	0.00125	0.43
7	F_P	1	0.03125	0.03125	10.82
8	TOTAL	7	0.28875		100

7. Pooled ANOVA :

Table 27 Pooled ANOVA Table Vc Copper plate

S NO	*FACTOR*	DOF	SUM OF SQUARES	VARIANCE	F - RATIO	% CONTRIBUTION
1	T_{ON}	1	0.101	0.101	81.299	34.731
3	I_P	1	0.151	0.151	121.439	52.092
3	F_P	1	0.351	0.031	15.076	10.413
4	ERROR	4	0.004	0.001		2.764
5	TOTAL	7	0.28875			100

SIGNIFICANT FACTORS

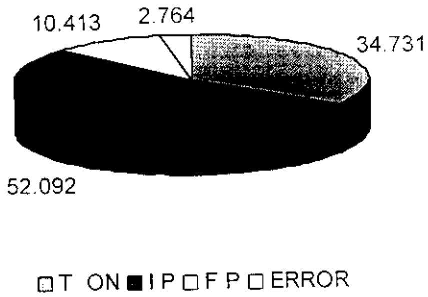


Figure 22 Vc Copper plate

The factors pulse on time, peak current and fluid pressure are most influencing factors. The factors other than are not significant when F-ratio test is carried out. The fluid pressure is not significant factor for steel plate

8. Optimum Conditions and performance :

Table 28 Optimum Conditions Vc Copper plate

S.No	FACTORS	LEVEL	LEVEL DESCRIPTION
1	T_{ON}	1	120
2.	T_{OFF}	1	40
3.	I_P	1	220
4.	W_T	1	600
5.	W_F	1	5
6.	F_T	2	7
7.	F_P	1	3

Expected result at optimum condition : 4.946 mm/min

9 . Interaction graphs :

By studying the interaction graphs pulse on time and fluid rate were found interacting

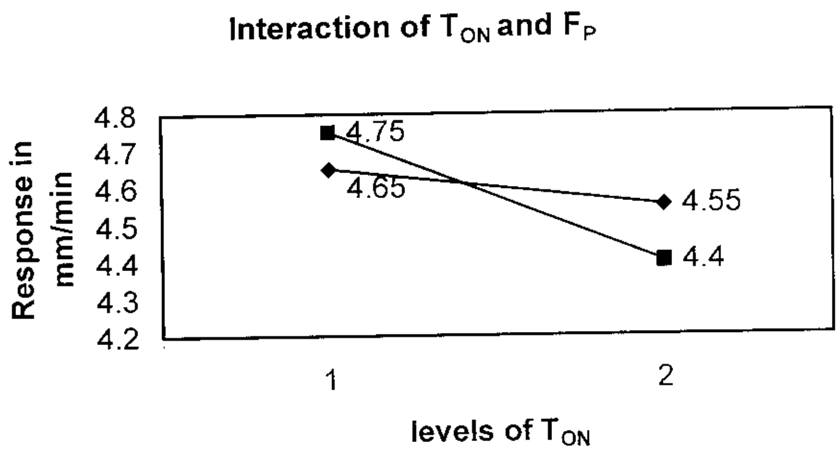


Figure 23 Interaction graph Vc Copper plate

11. Conducting Confirmation experiment :-

A confirmation experiment is performed by conducting a test using a specific combination of the factors and levels. The purpose of confirmation experiment is to validate the conclusions drawn during the analysis phase

Conducting a verification experiment is a critical and final and indispensable part of the Taguchi method based project. Its aim is to verify the optimum conditions suggested by the experiment estimating how close are the expected results with the real ones. The confirmation experiment was conducted based on the analysis. The parameters optimum levels & expected results are shown below

Steel plate:

Optimum level for Surface Roughness :

Table 29 Optimum Level Ra Steel Plate

S. No	T_{ON}	T_{OFF}	I_P	W_T	W_F	F_R	F_P
1	120	48	230	800	8	10	5

Expected Result from analysis : 2.001 microns

Confirmation Experiment result : 2.1 microns

Optimum level for cutting speed :

Table 30 Optimum Level Vc Steel plate

S. No	T_{ON}	T_{OFF}	I_P	W_T	W_F	F_R	F_P
1	130	40	250	600	4	10	10

Expected results from analysis : 3.34 mm/min

Confirmation Experiment result : 3.3 mm/min

Copper Plate :

Optimum level for surface Roughness :

Table 31 Optimum Level Ra Copper plate

S. No	T_{ON}	T_{OFF}	I_P	W_T	W_F	F_R	F_P
1	120	45	220	900	3	7	3

Expected results from analysis : 3.085 microns

Confirmation Experiment result : 3.2 microns

Optimum level for cutting speed :

Table 32 Optimum Level Vc Copper plate

S. No	T_{ON}	T_{OFF}	I_P	W_T	W_F	F_R	F_P
1	120	40	220	600	3	7	5

Expected results from analysis : 4.94 mm/min

Confirmation Experiment result : 4.9 mm/min

Results and Discussion

RESULTS AND DISCUSSION

The Taguchi method is employed to find out the main influencing parameters that affect the various machining criteria in the present set of study. Taguchi method is a best suited method for achieving a optimum machining performance with a minimum effort. The pulse parameters are found to be significant for both surface roughness and cutting speed.

The ANOVA table for analysis on experiment conducted for steel plate indicates that there are four factors influencing the responses, they are

T_{ON} , T_{OFF} , I_P , F_P

The other factors are pooled. There is a slight change in the percent contribution before and after pooling. The percent contribution of pulse off time factor is 49.377% but after pooling the contribution is 10.978%. The maximum contribution is by pulse off time and pulse peak current and others are considerably weak. The percent contribution of factors are shown in table 33

Table 33 Factors and Contribution for Ra Steel Plate

S NO	FACTORS	% CONTRIBUTION
1	PULSE ON TIME	10.9
2	PULSE OFF TIME	49.15
3	PEAK CURRENT	26.697
4	FLUID PRESSURE	10.977

The surface roughness will be minimum if the levels are set under the optimum conditions as given below in the table 34 and expected performance is 2.001 microns

Table 34 Optimum Level Ra Steel plate

S NO	FACTORS	LEVEL
1	PULSE ON TIME	120
2	PULSE OFF TIME	48
3	PEAK CURRENT	230
4	WIRE TENSION	800
5	WIRE FEED	8
6	FLUID RATE	10
7	FLUID PRESSURE	5

Analysis for cutting speed show that pulse on time and pulse off time contribution is more and others factors are pooled to conduct F-ratio test and the factors have least effect on the response. The table35 shows the percent contribution. Pulse off time is contributing more towards response

Table 35 Factors and Contribution for Vc Steel Plate

S NO	FACTORS	% CONTRIBUTION
1	PULSE ON TIME	21.62
2	PULSE OFF TIME	72.072

The cutting speed will be maximum if the parameters and levels are set the optimum conditions as given below in the table36 and the expected performance is 3.3 m/min

Table 36 Optimum level for Vc Steel plate

S NO	FACTORS	LEVEL
1	PULSE ON TIME	130
2	PULSE OFF TIME	40
3	PEAK CURRENT	250
4	WIRE TENSION	600
5	WIRE FEED	4
6	FLUID RATE	10
7	FLUID PRESSURE	10

For copper plate the parameters influencing the surface roughness remains same as for the steel plate. The expected performance is 3.085 microns. The pulse off time contributes more towards response and others are less. The factors having small variances are pooled.

Table 37 Percent contribution for Ra Copper plate

S NO	FACTORS	% CONTRIBUTION
1	PULSE ON TIME	7.354
2	PULSE OFF TIME	51.473
3	PEAK CURRENT	24.509
4	FLUID PRESSURE	19.7

The optimum conditions for surface roughness are shown in table 38. The minimum surface roughness is obtained by setting this level.

Table 38 Optimum level for Ra Copper plate

S NO	FACTORS	LEVEL
1	PULSE ON TIME	120
2	PULSE OFF TIME	45
3	PEAK CURRENT	220
4	WIRE TENSION	900
5	WIRE FEED	3
6	FLUID RATE	7
7	FLUID PRESSURE	3

Analysis for cutting speed indicate the three factors namely pulse on time, Peak current and fluid pressure influence the cutting speed. Whereas the fluid pressure has no effect on the steel plate

Table 39 Percent Contribution for Vc Copper plate

S NO	FACTORS	% CONTRIBUTION
1	PULSE ON TIME	34.731
2	PEAK CURRENT	52.092
3	FLUID PRESSURE	10.413

The optimum conditions for cutting speeds are

Table 40 Optimum level Vc Copper plate

S NO	FACTORS	LEVEL
1	PULSE ON TIME	120
2	PULSE OFF TIME	40
3	PEAK CURRENT	220
4	WIRE TENSION	600
5	WIRE FEED	3
6	FLUID RATE	7
7	FLUID PRESSURE	5

The confirmation experiment for copper plate doesn't shows improved results. There is slight deviation from the expected performance. The expected result for surface roughness value is 3.002 microns and about 3.2 microns was obtained. But the minimum Ra value from the experimental results was 3.2 microns, the same combination can be set for operating the machine.

CONCLUSION

CONCLUSION

In an extremely complicated machining process like wire cut EDM machine which is controlled by more than ten machining parameters, the situation is really tough for finding the different parametric combinations for a variety of jobs

An attempt is made to find the optimum conditions of the parameters in order to get minimum surface roughness and maximize the cutting speed. About seven parameters were short listed which is to be influencing parameters in the response and among those parameters few have more effect on the response.

It is found that there is an improvement in surface finish and cutting speed from the confirmation experiment. Comparing both the analysis for surface roughness and cutting speed the optimum conditions vary. It is impossible to achieve minimum surface roughness and maximum cutting speed simultaneously. A better surface finish is achieved making a suitable trade off between the productivity

The technique taken for solving the problem yielded better results and its applicability is validated. Instead of going for other techniques DOE Taguchi technique is easier to perform and can be completed in short period. The Qualitek-4 software is an another tool helpful in analyzing part. The technique can be used to find the combination of parameters for variety situations like different metals, thickness & varying compositions of materials.

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