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OPTIMIZATION OF WIRE ELECTRIC DISCHARGE MACHINING PARAMETERS USING TAGUCHI APPROACH

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ABSTRACT

Wire electric discharge machining (WEDM) has become an important non-traditional machining process, as it provides an effective solution for producing components made of difficult to machine materials like Titanium, Zirconium, Hastalloy etc. and also produce intricate shapes which are not possible by conventional machining methods. Due to large number of process parameter and responses lots of researchers have attempted to model this process. This study reviews the research trends in wire electrical discharge machining on relation between different process parameters and responses including material removal rate and surface roughness.

Keywords: Wire electric discharge machine, non-traditional machining, material removal rate, surface roughness

INTRODUCTION

Wire electric discharge machining (WEDM) is one of the most popular and advanced Thermo-electrical, non-conventional machining method mainly used in the production of precision components in extremely hard material. The technology of the wire EDM process is based on the conventional EDM sparking phenomenon utilizing the widely accepted non- contact technique of material removal with a difference that spark is generated at wire and work piece gap. This gap is completely filled with a dielectric fluid which will flush away the removed material from Spark gap. This process is used in the automotive and aero-space, die & tool manufacturing industries. It is possible to obtain and measure the desired surface finish on a work piece during machining in wire EDM process in any intricate shape of the work-piece irrespective of its hardness.

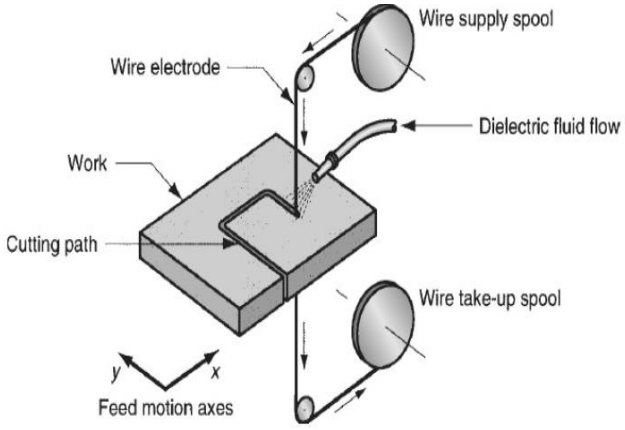

Fig.1. Wire electric discharge machine process

It is very important to know the process capabilities of any machining process, so that the parameters can be set in such a way that the process can give optimum results. The work mainly focused on the evaluation of influence of process parameters on the process capabilities of the wire electrical discharge machine and process also optimizing the process parameters for higher material removal rate and lower surface roughness. While doing this process different techniques are used to analyze the parameters for better utilization of the process.

LITERATURE REVIEW

There are number of researchers who worked on wire electric discharge machining and according to required process parameters and response variables, we are going to study following few papers:

Tonday and Tigga [1] studied different process parameters on wire electric discharge machine such as pulse on time, pulse off time, cutting voltage and their effect on material removal rate and kerf width using Inconel 718 as workpiece material. They concluded that wire electrical discharge machining can be effectively implemented on Inconel 718.

Bobbili et al. [2] studied wire electric discharge machining process for armour material using pulse off time, pulse on time and voltage as process parameters and surface roughness, material removal rate and deflection as output parameters, they concluded the experiment gives same result as that of for normal wire electrical discharge machine and as more effect of deflection.

Ganesh Dongre et al. [3] focused on multi-objective optimization by considering different process parameters such as wire diameter, workpiece height, duty cycle, current and their effect on surface roughness. For optimization they implemented Response surface method. After performing experiment it was seen that silicon wafers can be more effectively cut using the wire electrical discharge machining process.

Subrahmanyam and Nancharaiah [4] optimized process parameters such as pulse on time, pulse off time, servo voltage and their effect on material removal rate and surface roughness using Inconel 625

using Taguchi method. After carrying out experimentation they concluded that MRR is increased as pulse off time increases and has the highest contribution of 61.90% and for minimum surface roughness pulse off time and pulse on time contribute about 67.09%.

G. Daniel et al. [5] studied the optimization of material removal rate by varying process parameters such as pulse on time, pulse off time, flushing pressure, wire tension and servo voltage using Inconel 718 and molybdenum (0.25 mm diameter) tool, they referred Taguchi method and MATLAB for optimization and Artificial neural network is implemented to get response. After conducting experiment, they concluded that proposed Artificial neural network algorithm is useful in reduction of production time and set-up time, along with the reduction in cost of wire electrical discharge process and the developed artificial neural network model results close agreement with experimental values.

- **Objectives of the proposed study:**

This experiment is carried out to study the effect of process parameters on following elements

1. To identify and select process parameters influencing the wire electric discharge machine.
2. To perform experiment with wire electric discharge machining as per Taguchi method.
3. To analyze experimental results for response variables such as material removal rate and surface roughness.
4. To optimize the process parameters using Analysis of variance.

- **Process parameters:**

Below are some parameters which, will be considered during experimentation

Input parameters:

1. Pulse on time (µs)
2. Wire tension (gm.)

Response variables:

1. Surface roughness (µm)
2. Material removal rate (mm3/min)

- **Proposed Work:**

1. Problem identification for the wire electric discharge machining.
2. Literature review for various parameters on wire electric discharge machining and various optimization and prediction techniques used for determining the optimum process parameters.
3. To study the effect of behavior of various input parameters of wire electric discharge machining operation such as pulse on time, pulse off time, wire tension and servo voltage on the output parameters like material removal rate, surface roughness.
4. Perform number of trial experiments on wire electric discharge machining setup.

5. To determine the optimum parameters using Taguchi method and validate those parameters with the help of experiments.
6. To determine the optimum parameters using Analysis of Variance and validate those parameters with the help of experiments.
7. Report writing: All the results obtained after analyzing, can be collected and put in the right format with proper sequence.

MATERIAL AND EXPERIMENTATION

MATERIAL

Tool material- Zinc Coated Brass (0.25mm diameter)

- **Workpiece material-** Hastalloy C22
- **Characteristics of Hastalloy C22:**

Hastalloy C22, also known as alloy C22, is a versatile austenitic nickel-chromium-molybdenum-tungsten alloy with enhanced resistance to pitting, crevice corrosion and stress corrosion cracking. The high chromium content provides good resistance to oxidizing media while the molybdenum and tungsten content give good resistance to reducing media. This nickel steel alloy also has excellent resistance to oxidizing aqueous media including wet chlorine and mixtures containing nitric acid or oxidizing acids with chlorine ions. This nickel alloy also offers optimum resistance to environments where reducing and oxidizing conditions are encountered in process streams. This is beneficial in multi- purpose plants where such “upset” conditions occur frequently. This nickel alloy resists the formation of grain-boundary precipitates in the weld heat-affected zone, thus making it suitable for most chemical process applications in the as-welded condition. Alloy C22 should not be used in service temperatures above 1250° F due to the formation of detrimental phases which form above this temperature.

EXPERIMENTATION

Electronica Ecocut wire cut electrical discharge machine version 1.25T works similar to conventional electrical discharge machine process, high voltage pulse train containing short period ON & OFF time is applied between workpiece & electrode (wire) where wire is surrounded by deionized water and works as dielectric. During ON time dielectric breaks & becomes conductive to pass high peak current & melts the material. Wire electrode mainly from brass or stratified copper of diameter ranging from 0.25 mm to 0.33mm is used to erode the material.

The wire is continuously getting refreshed by wire pulling mechanism & passing through very tight tolerance diamond wire guides upper & lower of work piece. The rotating wire is continuously under specific tension. The water is used as dielectric flushed with high pressure from upper & lower nozzles to form the water column around the wire.

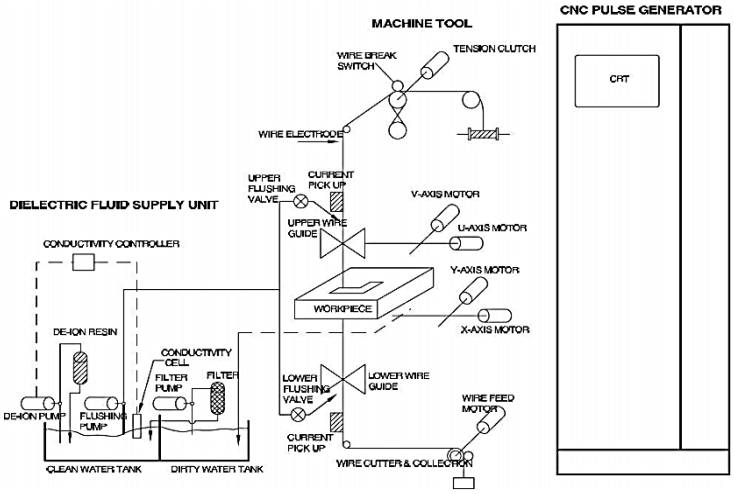

Fig. 2. Schematic diagram of wire electric discharge machine

- Ranges

Pulse on time	0-31 µs
Pulse off time	0-63 µs
servo feed	0-999 mm/min
Servo voltage	0-99 V
Wire feed	0-15 m/min
Wire tension	0-15 gm.

- **Design of Experiments:**

1. Design of experiment is a substantial statistical procedure for product/process design improvement and solving problems occurring during production of parts.
2. Design of Experiments is an experimental strategy for examine the effect of multiple factors on the output.

3. Taguchi has formulated a systematic method to make use of the Design of Experiments (DOE) method to improve the product quality and processes.

- **Process parameters:**

Table 2. Process parameters and their levels

Parameters	**Levels**		
Pulse on time Ton (µs)	110	113	116
Wire tension (gm.)	7	8	

- **Experimental setup:**

Fig. 4. shows the experimental setup of wire electric discharge machine. The wire (Zinc Coated Brass wire) is feed through the guide and nozzles. The workpiece (Hastalloy C22) is mounted on the worktable. Wire and workpiece is adjusted manually as per requirement, keeping minimum gap of 0.2mm.

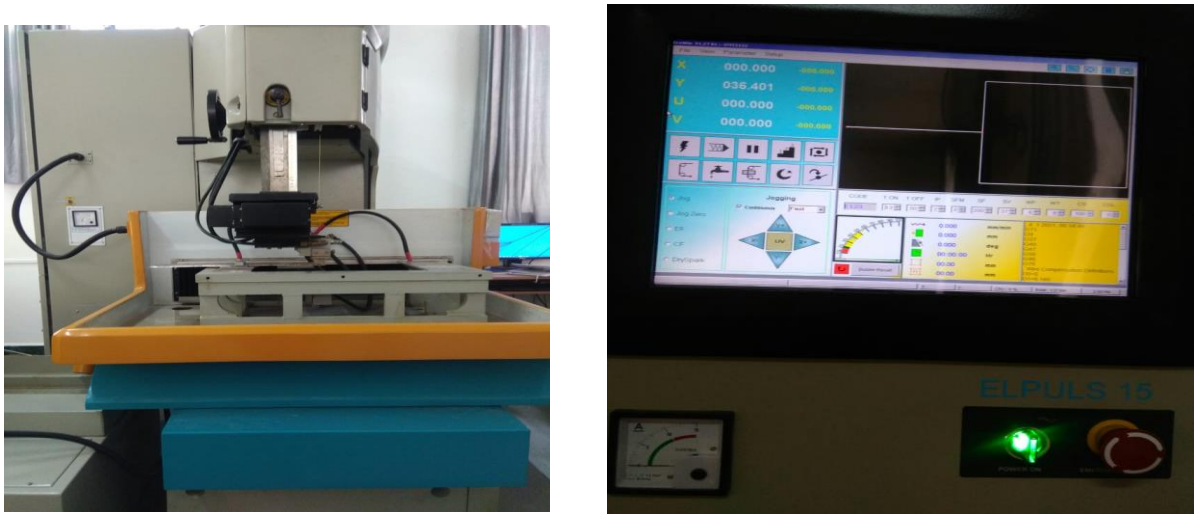

Fig. 4. Experimental setup

- **Trial experiment:**

Based on literature review and hands-on experiments, three sets of parameters were selected and trail experiments is carried out. Trail experiments were conducted as per Design of Experiments (DoE). The orthogonal array L9 array is selected. Material used for trail experiments: Workpiece material- Hastalloy c22 Wire material- Zinc coated brass Dimensions for trail experiments: 10mm*10mm*10mm

- **Taguchi's L9 array:**

Table 3. Input parameters

Trial no.	**Pulse on time (µs)**	**Wire tension (gm.)**
1.	110	7
2.	110	8
3.	110	9
4.	113	9
5.	113	7
6.	113	8
7.	116	8
8.	116	9
9.	116	7

RESULT AND CONCLUSION

- Material removal rate (MRR):

Material removal rate is a very important parameter which influences productivity of any process. As material removal rate increases, the economic benefits of using wire electric discharge will be worthy for any firm. This factor depends upon number of input parameters which are related with wire electric discharge.

$$\text{MRR} = \frac{\text{LBH}}{\text{T}}$$

Where,

L= length of slot in mm

B= kerf width in mm

H= thickness of workpiece material in mm

T= time taken in minute

- Surface roughness:

Surface roughness is also the very important parameter whose value is required to be minimized. To obtain good surface roughness, certain factors need to be controlled and there are electrical parameters, dielectric fluid, work piece material. To measure surface roughness Taylor Hobson surface roughness tester is used.

Table 3. Input parameters and results for hands-on experiments

Levels	Pulse on time (µs)	Wire tension (gm.)	Material removal rate (mm3/min)	Surface Roughness (µm)
1	110	7	6.25	1.06
2	113	8	7.50	0.98
3	116	9	8.75	1.07

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