

# Study and Optimization of Process Parameters for the Machining of Nimonic 75 Alloy on EDM Using Electrodes of Different Material – A Review

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**ABSTRACT:** EDM is a non Conventional Machining process used for the purpose of machining of the metals and their alloys which are otherwise difficult to machine on conventional machining processes. Nimonic alloy is one such alloy made of nickel and chromium. Due to their high strength these alloys are also difficult to machine. Their machining is preferably done on the Electric discharge machine using electrodes of various materials. Experiments have been performed to check for the surface finish obtained by using copper electrode on Nimonic alloy on the EDM. An experiment will be performed for the purpose of specifying the optimum electrode material for the purpose of machining the Nimonic alloys. The electrode materials used for this purpose are Copper, Brass and copper tungsten. Experiments concluding the best electrode material suitable for the purpose of machining the Nimonic 75 alloy among the above electrodes have not been performed. The conclusion obtained from this experiment will be useful to know which electrode will give optimum result considering the same fixed and variable process parameters of machining the Nimonic alloy on the EDM

**KEYWORDS:** Electric Discharge Machine, Nimonic 75 alloy, Process parameters, machining characteristics, electrode material

## I. INTRODUCTION

Electrical discharge machining also known as EDM has been proven as an alternative process for machining complex and intricate shape. It is a non-conventional machining method. In electrical discharge machining process electrical energy is used to cut the material to final shape and size. Efforts are made to utilize the whole energy by applying it at the exact spot where the operation needs to be carried out. For this different types of electrodes are used on EDM according to the work piece material. Any type of conductive material can be machined using EDM irrespective of the hardness or toughness of the material.

A super alloy, or high-performance alloy, is an alloy that exhibits several key characteristics: excellent mechanical strength, resistance to thermal creep deformation, good surface stability and resistance to corrosion or oxidation. The crystal structure is typically face-centered cubic austenitic. Super alloys are the alloys which possess comparatively higher mechanical and thermal strength in comparison to individual metals. These properties of the super alloys make them eligible for the purpose where in high strength to weight ratio of a material is expected for e.g. aerospace industry. Various super alloys are available for this purpose include Nimonic alloy, Hastelloy, Inconel, Waspaloy, Rene alloys, Haynes alloys, Incoloy etc.

## II. EDM PROCESS PARAMETERS

The process parameters which will influence the experiment of optimizing while machining of the Nimonic alloy are listed below

- i) Discharge current - It points out the different levels of power that can be supplied by the generator of the EDM machine and represents the mean value of the discharge current intensity.
- ii) Pulse-on time - It is the duration of time ( $\mu\text{s}$ ) the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this pulse-on time. This energy is controlled by the discharge current and the duration of the pulse-on time.
- iii) Pulse-off time - It is the duration of time ( $\mu\text{s}$ ) between the two successive sparks (pulse-on time). This time allows the molten material to solidify and to be wash out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off-time is too short, it will cause sparks to be unstable.
- iv) Duty cycle - It is a percentage of the pulse-on time relative to the total cycle time. This parameter is calculated by dividing the pulse-on time by the total cycle time (pulse-on time plus pulse-off time). The result is multiplied by 100 for the percentage of efficiency, called duty cycle.
- v) Dielectric pressure - This is the flushing pressure of the dielectric jet which removes the chip or debris produced during the EDM process away from the gap zone. This value of pressure is measured by pressure gauge existing in the EDM machine.
- vi) Polarity - The machine can run either in normal polarity or reverse polarity. The polarity normally used is straight (normal polarity) in which the tool is negative and work piece is positive, while in reverse polarity the tool is positive and work piece is negative.

## III. MACHINING CHARACTERISTICS

The effectiveness of EDM process is evaluated in terms of its machining characteristics. The short product development cycles and growing cost pressures have forced the die and mould making industries to increase the EDM efficiency. The EDM efficiency is measured in terms of its machining characteristics viz. material removal rate, surface roughness and tool wear rate. The most important machining characteristics considered in the present work are:

- i) Surface Roughness ( $R_a$ ): Surface finish is an essential requirement in determining the surface quality of a product. The average surface roughness is the integral absolute value of the height of the roughness profile over the evaluation length ( $L$ ) and was represented by the equation given below.

$$R_a = \frac{1}{L} \int_0^L |Y(x) dx|$$

Where 'L' is the length taken for observation and 'Y' is the ordinate of the profile curve.

- ii) Material removal rate (MRR): Material removal rate is a desirable characteristic and it should be as high as possible to give least machine cycle time leading to increased productivity. Material removal is the difference of weight of work-piece before machining and after machining. It is calculated by the formula [1.2] as given below.

$$MRR = \frac{W_i - W_f}{\rho_w t}$$

where,  $w_i$  is the initial weight of work-piece in g;  $W_f$  is the final weight of work-piece after machining in g;  $t$  is the machining time in minutes and  $\rho_w$  is the density of work piece material.

- iii) Tool Wear Rate (TWR): Tool wear rate is the difference of electrode weight before and after machining and is expressed as:

$$TWR = \frac{E_i - E_f}{\rho_e t} \quad \text{mm}^3/\text{min}$$

where  $E_i$  is the initial weight of electrode in g;  $E_f$  is the final weight of electrode after machining in g;  $t$  is the time of electrode in min;  $\rho_e$  is the density of electrode material.

### III. RESEARCHES ON EDM OF NIMONIC ALLOY

(1) Performance and surface integrity of Nimonic75 alloy machined by electrical discharge machining

The ongoing developments in the field of materials science have developed many high strength and temperature resistant (HSTR) metal alloys that are difficult to machine by the conventional machining. Electrical discharge machining is one of the commonly used non-conventional machining processes used to machine hardened tool steels and conductive advanced materials.

(2) To study the effect of copper tungsten electrode material removal rate on EDM.

EDM is used for machining of parts of aerospace, automobile, nuclear and surgical industry. In this research paper an attempt has been made to study the effect of cryogenic treatment on powder metallurgy copper tungsten electrode at different machining parameters, i.e., peak current, gap voltage, duty cycle, polarity and electrode type during EDM of H11 tool steel. H11 is basically 5% chromium and 1.5% molybdenum hot work tool steel. The presence of molybdenum in H11 increases its hardness and is usually known as difficult to machine by conventional machining process. This research work was undertaken to study the machining performance of EDM with different electrodes, i.e., PM copper tungsten (CuW) (75% cu and 25% tungsten) and cryogenically treated PM copper tungsten (CuW) tool electrode on H11 hot work tool steel. A L18 Taguchi's standard orthogonal array is used for experimental design by varying different input machining parameters such as current, gap voltage, duty cycle, polarity, retract distance and their effect on material removal rate (MRR).

(3) Performance of different electrode Materials in EDM of super alloy.

The aim of the study is investigation and optimization of electrical discharge machining for inspecting the machinability of Inconel600 alloys using Taguchi method. Inconel600 alloys are a type of material highly corrosion resistant (Nickel –Chromium super alloy). As Inconel600 is highly brittle, this is not suited to be machined of traditional machine manufacturing. This paper utilizes electrical discharge machining, which is thermal processing work pieces are not affected by mechanical properties of materials. This experiment utilizes the Taguchi method and L9 orthogonal table to obtain the electrode material, peak current, pulse-on time and gap voltage in order to explore the material removal rate, electrode wear rate and surface roughness. The influence of each variable and optimal processing parameter will be obtained through ANOVA analysis and verified through experimentation to improve process.

(4) Investigation of surface integrity with copper tungsten electrode on EDM

The study in this paper presents the EDM process with copper tungsten electrode of 2 mm diameter to establish the influence of EDM parameters on various aspects of the surface integrity of AISI 4340 steel. The residual stress induced by the EDM process is measured using the x-ray diffraction method.

(5) MRR improvement in die sinking EDM – A review

Electrical discharge machining (EDM) is one of the earliest non-traditional machining processes. EDM process is based on thermoelectric energy between the work piece and an electrode. Material removal rate (MRR) is an important performance measure in EDM process. Since long, EDM researchers have explored a number of ways to improve and optimize the MRR including some unique experimental concepts that depart from the traditional EDM sparking phenomenon. Despite a range of different approaches, all the research work in this area shares the same objectives of achieving more efficient material removal coupled with a reduction in tool wear and improved surface quality. The paper reports research on EDM relating to improvement in MRR along with some insight into mechanism of material removal.

(6) Growth of EDM and its application – A review

Globalization is making the manufacturers to invest and invent in the manufacture / production of sophisticated and quality products to meet ever changing needs of the customer. Thus, the research in manufacturing has been

concentrated towards the high speed machining involving CNC Machines, Robots and Automated Handling Systems with the emergence of computers in Engineering on one side and the development Unconventional Machining such as Chemical Machining, Laser Beam Machining (LBM), Electron Beam Machining (EBM) and Electron Discharge Machining (EDM) on the other side. Out of them, the environment of Chemical Machining is found to be hazardous, whereas LBM and EBM require huge investments in comparison to EDM. Therefore, the EDM is widely used in manufacturing. In the present paper, about 111 research papers are reviewed on the major topics of EDM research. It also reports on the research related to the adaptive monitoring and control of process and the feasibility of different strategies of obtaining the optimal machining conditions. EDM as well as WEDM industrial applications are reported together with the hybrid machining process.

(7) Response surface modeling of EDM process.

Electric Discharge machining is used to produce complex shapes that would be difficult to produce in conventional machine tools and also good surface finish can be obtained in EDM. The work material EN24 is machined by using copper as electrode. The EN24 contains nickel, chromium and molybdenum and it is used in automobile and aircraft transmission components. For this reason, the EN24 is experimentally investigated with the machining parameters for achieving maximum MRR and minimum electrode wear rate and surface roughness. The RSM is also used to identify the machining parameter responses on MRR, EWR and SR. The input parameters are peak current, pulse on time and pulse off time. The experimental design is done using Box design of RSM. Regression equations are formulated based on the experimental results. The effects of input parameters are analyzed on MRR, EWR and SR.

#### IV. RESULTS AND DISCUSSIONS

Major results and discussion with respect to the researches above are discussed below

(1) In this study effect of machining parameters like tool polarity, current, pulse on-time and voltage has been investigated on surface roughness of Nimonic 75 alloy using Taguchi's experimental design technique. From the S/N ratio plots it was observed that tool polarity, pulse on-time and current are most influential parameter that affects surface roughness in EDM. The surface machined by the negative tool polarity was found to be smoother than the positive tool polarity. The deposition rate of the negative polarity tool electrode was comparatively more than the positive polarity tool electrode. The maximum deposition of carbon was observed on the surface machined with positive polarity tool electrode.

(2) It was found that material removal rate is maximum with cryogenically treated powder metallurgy copper tungsten (Cu-W) tool electrode with peak current (14A) at gap voltage (60V) and duty cycle (0.72) in +VE polarity.

(4) The Experimental values show that the MRR, TWR and SR depend on the pulse on time and the current the higher the values the better these machining characteristics but only up to certain extent. After some time the values start decreasing with the increase in the process parameters.

These are various major results obtained based on the experiments performed on the machining of super alloys including Nimonic 75 alloy on EDM.

#### V. RESEARCH GAP, PROBLEM AND CHALLENGE

Super alloys are machined on the EDM. Nimonic alloy is one such super alloy on which optimization experiment can be performed in order to know which electrode will be suitable for its machining on the EDM. No such optimization work is done taking in to consideration electrodes of different materials and Nimonic alloy.

The objective of this article has been aimed to report the work carried out by various researchers in the field of EDM electrode and to bridge the gap between the untouched areas. After an elaborate scrutiny of the published work, the following number of gaps in the literature has been observed from the existing published work.

1. Most of the published work on EDM relates to optimization of other super alloy such as Inconel. There is not much published work on EDM of Nimonic alloy.

2. In addition, published works include work piece material such as hardened steel and it's machining on the EDM using copper as electrode Use of work piece material as Nimonic alloy and its process optimization on EDM using electrodes of different materials is not carriedout

## VI. CONCLUSIONS

This article presents a review of research work carried out in the determination and optimization of the process parameters for EDM. A number of research works based on various optimization techniques were reviewed including RSM, Taguchi method. A review of research work on various optimization techniques indicated that there were successful industrial applications of Taguchi method, RSM. These are robust optimization techniques to make experimental design insensitive to uncontrollable factors such as environmental parameters to predict responses and optimize the EDM process conditions in accuracy level. Research work has been carried out in order to devise better ways for the machining of the Nimonic alloys still there are shortcomings in the machining processes used for machining of the Nimonic alloy. Electrodes used in the EDM process are the one which play a key role in machining of super alloys. Using different electrodes it is tried to conclude the best electrode for machining of Nimonic 75 alloy.

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