Chapter 2
Potential Experimental Analysis of Electrical Discharge Machine Process Parameters on Stainless Steel ANSI 304

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Abstract In this research, the effect of electrical discharge machining (EDM) parameters such as pulse-on time (Ton), pulse-off time (Toff), voltage, (V), and current (I) on the material removal rate (MRR) in 304 stainless steel was studied. The experiments are carried out as per design of experiments approach using the L9 orthogonal array. From this study, it is found that different combinations of EDM process parameters are required to achieved higher MRR for 304. The contribution of each cutting parameters towards the MRR is also identified. The results from this study will be useful for manufacturing engineers to select appropriate EDM process parameters to machine stainless steel 304.

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2.1 Introduction

Electric discharge machining (EDM) is an advanced manufacturing process. It is the removal of segments of electrically conductive metals by electrical pulses between two terminals (electrode and workpiece) within the dielectric. The electrical discharge melts and vapourizes workpiece. The main goals of EDM manufacturers and users are to achieve a machining stability and high productivity. With the increasing demands of higher surface finish and machining of complex shape geometries, conventional machining process are now being replaced by non-traditional machining processes. The major advantage of the process lies in its capability to easily machine any electrically conductive material regardless of its mechanical properties.

EDM is carried out by means of electric sparks that jump between two electrodes subjected to a voltage and submerged in a dielectric fluid. Thus, the voltage applied to them must be enough to create an electric field of higher intensity than the dielectric strength of the fluid used in the process.

In this process the material is removed from the workpiece due to erosion caused by rapidly recurring electrical spark discharge between the workpiece and the tool electrode. There is a small gap between the tool and the workpiece. The workpiece and the tool are submerged in dielectric fluid. The commonly used dielectric fluids are EDM oil, deionized water, and kerosene.

2.2 Literature

This section describes the review of the literature relevant to this project. Data collections are used as a reference by researchers to gather information about the study that has been carried out. The literature review analyses the information gathered by journal paper publications from other researchers and the information collected from the internet. This literature review can help to address the issues that have occurred during the study prior to the start of the creation of this project.

2.2.1 Electrical Discharge Machining

By way of electrical discharge operations, EDM is used to achieve the appropriate form. The phase of substance removal has ended due to the current discharge between two electrodes. Dielectric fluid and electrical voltage play a very significant role in this process. As we note, non-conventional machining methods include electrical discharge machining operations. It is mainly used for hard metal machining

operations and for complicated operations, which with obsolete methods are almost impossible to do [1].

2.2.2   Die-Sinking

Two Russian scientists developed the die-sinking mechanism. In 1943, Lazarenko discovered means of avoiding tungsten electrical contact erosion due to electrical spark. They were unsuccessful in this task many times, but they discovered that if the electrodes were submerged in a dielectric solvent, the corrosion was more precisely regulated. This prompted them to create an EDM system that was used to deal with hard-to-machine materials like tungsten.

Two electrodes are mounted on the parts of the system, which are the work bench and the tool holder in this process. The electrodes both have to be electrically conductive. After that, with the assistance of the compressor, all electrodes are immersed in an insulating liquid dielectric. The EDM oil/kerosene/transformer oil is the dielectric. To get the appropriate shape and scale, set the machining parameters on the CNC controller for machining on the workpiece [1].

2.2.3   Wire EDM Process

The wire-cut sort of machine was established during the 1960s to make instruments (kicks the bucket) from solidified steel. In this cycle the apparatus anode is a type of wire. To dodge the disintegration of material from the wire making it break, the wire is twisted between two spools with the goal that the dynamic portion of the wire is continually evolving.

The wire-cut EDM measure is additionally called the electric release wire cutting cycle. It is utilized for the delivering a few-dimensional complex shapes utilizing an electro warm instrument for disintegrating the material from a slim single abandoned by controlling a metal wire encompassed by deionized water which is utilized to the lead power [1].

2.2.4   Dielectric Fluid

Dielectric fluid is used as a coolant, flushing medium, and a conductor of the catalyst as well. This plays a very significant role in the EDM process. The requirements are:

1. To act as insulation between tools and the workpiece, the dielectric should have compulsory and continuous dielectric strength before the breakdown voltage is reached.

2. Once the spark ejection has happened, it must de-ionize rapidly.
3. To have an efficient cooling mechanism and clear the swerve particles from the machining gap, it must require limited viscosity and a friendly moistening capacity.
4. During the spark, it should be flushed out of the element produced from the void. This is the dielectric fluid's most vital function. Insufficient flushing can cause arcing to reduce the electrode's life and increase the machining time.
5. Chemically, it should be neutral in order not to attack the instrument, function and the movable table or tank.
6. Its flash point should be high enough that no fire risks are present.
7. Any harmful vapours should not be released.
8. These properties should be preserved by temperature variations, degradation through operating residuals and decomposition materials.

It should be fundamentally economical and readily usable [1].

2.2.5   EDM Machine Components

The first part of EDM is the tool feeder that should be servo-driven in order to retain a driven distance. Regulated differences are an critical factor in the incidence of active discharges between the two electrodes. The second part is the power supply, which provides voltage and current in a particular ON/Off time in the form of pulses. The circulation unit is the third component; this unit extracts the dielectric from the debris, then flushes it back to the void. However, due to the variations in the method of spark erosion machining, the system part could be different [2].

2.2.6   Material Removal Rate

The MRR is the quantity of material extracted per unit of time, specifically aimed at efficiency improvement. This needs to be maximized in roughing operations and the processing of large batches. However, when it comes to completing operations, it is a consideration to be put on hold, forcing roughness and accuracy to the forefront. Both are often used for low roughness, usually low cutting speeds and feed per tooth, as MRR is usually very low for finishing.

2.2.7   Surface Quality Analysis

The surface is synonymous with different surface properties, such as the profile of microhardness, surface roughness, geometric residual tension, crack density, white

layer, and crack density. In order to meet the growing anxiety of complicated part efficiency, longevity, and reliability, the surface morphology of a machined surface is increasingly becoming more significant. It plays an important role in the inspection of product geometry, roughness, and dimensional precision in the industry and manufacturing industries. The measuring of the surface integrity factor is a time-consuming procedure using precious instruments such as microhardness testers, XRD, SEM, and roughness testers for the surface. A major consideration used to determine EDMed surface consistency is the surface roughness. In order to determine the effect of EDM parameters to account for SR in the specimen, the surface profile on the machined samples was calculated using various equipment, namely, surface roughness tester, atomic force microscopy (AFM), 3D profiler, etc. [3].

2.2.8 Taguchi Method

The Taguchi approach involves reducing the variance of a procedure through rigorous laboratory design. In order to coordinate the criteria influencing the method and the thresholds at which they should be varied, the experimental architecture suggested by Taguchi requires the use of orthogonal arrays; it enables the gathering of the required data to decide which variables impact product quality most with a minimal amount of experimentation, saving time and energy. The expression 'signal' in this system represents the desired value (mean) for the output characteristic and the word 'noise' represents the unfavourable value for the output characteristic, i.e., standard deviation (S.D). The S/N ratio is, thus, the ratio between the mean and the S.D. Determined by the shape of the features, various levels of S/N ratios are used for the Taguchi method-the lower-the-better, the higher-the-better, and the nominal-the-better. The main steps for designing experiments using the Taguchi method are as follows [4]:

- Description and evaluation of quality attributes and method parameters.
- Identification of the number of parameter levels and potential interactions with the parameters of the operation.
- Assignment of process parameters to the orthogonal array that is chosen.
- Conduction of orthogonal array-based experiments.
- Calculation of S/N ratio.
- Analyze the experimental results using the S/N ratio and ANOVA.
- Selection of the optimal levels of process parameters.
- Verifying the optimum parameters of the mechanism via the validation experiment.

The main step in the Taguchi system to achieve high efficiency without raising costs is the optimization of process parameters. The Taguchi system, however, was initially developed to optimize single output functions. The S/N ratio is the ratio of signal to noise according to the Taguchi equation, where the signal reflects the desired value and the unwanted value is expressed by noise. The Ra and Kf response is used to use the equation to measure the signal-to-noise ratio (S/N). Now, the experimental

effects are translated into a ratio of signal-to-noise (S/N). Since the minimum surface roughness and kerf width is required, the lower-the-better characteristic is used for calculating the S/N ratio. The best atmosphere would be the one that will reach the lowest S/N ratio [5].

2.3 Methodology

The research effectively the methods used to complete and perform well this project. This experimental project was formulated prior to the implementation of the work. The method is used to achieve the objective of the project that will accomplish a perfect result. It consists of an L-27 orthogonal array using the Taguchi design, selection of workpiece, experimental setup, tool design, and calculation of material removal rate and surface roughness. A Gantt chart was developed which consists of activity duration estimation and the development of the project schedule.

2.3.1 Research Structure

The problem needs to be understood so it can be solved. Next is about the objective of this research and how the goal can be achieved, and the scope of the study is the initial planning process. It typically involves drawing up a list of everything in this research in order to create the framework of the research.

2.3.2 Experimental Setup

Using the electric discharge machine unit, the tests were carried out, the electrode polarity was set as positive while that of the workpiece was negative. EDM oil was the dielectric fluid that was used. The EDM consists of the following parts:

  i.   Dielectric reservoir, pump, and circulation system.
 ii.   Power generator and control unit.
iii.   Working tank with work holding device.
 iv.   X–Y working table.
  v.   The tool holder.
 vi.   The servo system for feeding the tool.

2.3.3 Selection of the Workpiece

In every single mechanical application, AISI 304 stainless steel is one of the most widely used materials and records about 50% of the production and utilization of hardened steel worldwide. It has become the most favoured commodity over others as a result of its tasteful outlook in engineering, prevalent physical and mechanical properties, resistance to corrosion and plastic substances, weldability. Numerous standards and non-customary AISI 304 treated steel machining methods are available.

2.3.4 Tool Design

A variety of metals such as copper, metal, aluminium amalgams, silver blends, and so on will be the instrument material used in electro discharge machining. Copper is the content used in this experiment. The cathode of the instrument is a circular form with a 21 mm measurement.

2.3.5 Mechanism and Measurement of the MRR

MRR is the speed at which the workpiece is separated from the material. During the machining process, electric sparks are formed between the instrument and hence the workpiece. Each spark creates a tiny hole and hence induces material erosion. The MRR is defined by the ratio of the difference in weight between the material density and the machining time of the workpiece before and after machining:

$$\text{MRR} = \frac{Wi - Wf}{t(p)}$$

which is Wi = initial weight before the machining process
   Wf = final weight after the machining process
   t = machining time
   p is the density if AISI 304 SS.

2.3.6 Mechanism and Evaluation of Surface Roughness

Surface roughness is the indicator of surface which takes another expression here. It is classified in microns. The surface is rough if the value is high, and the surface is smooth if the value is low. The roughness values are denoted by Ra. For the final value, the arithmetic median of three readings is taken.

2.3.7 Design of Experiments Analysis

In order to increase the efficiency of producing products referred to as Taguchi techniques, Genichi Taguchi developed several statistical methods. This architecture offers a possible and practical way for multiple goods to be built that can work continuously over a good variety of conditions. Both static and dynamic response experiments are given by Minitab. In an orthogonal array, the arrangement of tests is used to find the most powerful combination of input variables. The input parameters considered in this experiment are current, Ton, and Ð. The design becomes a 3-level 3 factorial Taguchi design because three variables are picked. For the tests to be performed, the L27 orthogonal array was selected.

2.4 Conclusions

The use of stainless steel 304 to optimize the EDM multiple performance characteristics has been successfully reported in this paper. Optimization of multiple performance characteristics was simplified through this approach. The experimental result for the optimal setting shows that there is considerable improvement in the process. It is shown that the performance characteristics of the EDM process namely material removal rate, electrode wear ratio, and surface roughness are improved together by using this method.

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