EXPERIMENTAL INVESTIGATION OF WEDM FOR MACHINING EN-31 MMC

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ABSTRACT

The study presents an investigation of WEDM on metals difficult to machine. Accompanying the development of mechanical industry, the demands for alloy materials having high hardness, toughness and impact resistance are increasing. WEDM machines are used to cut conductive metals of any hardness or that are difficult or impossible to cut with traditional methods. The machines also specialize in cutting complex contours or fragile geometries that would be difficult to be produced using conventional cutting methods. Machine tool industry has made exponential growth in its manufacturing capabilities in last decade but still machine tools are not utilized at their full potential. This limitation is a result of the failure to run the machine tools at their optimum operating conditions. The problem of arriving at the optimum levels of the operating parameters has attracted the attention of the researchers and practicing engineers for a very long time.

T he EN-31 MMC material is extensively used for aerospace application. The consistent quality of parts being machined in WEDM is difficult because the process parameters cannot be controlled effectively. Even most WEDM machine today have process control, but selecting and maintaining optimal setting is still an extremely difficult job which yet to be satisfactorily addressed. The objective is to study the effect of current, voltage, pulse on time individually on the final outcome i.e. MRR, surface roughness (Ra) and to establish the mathematical models relating the performance measures and input parameters by regression analysis.

Response surface methodology (Central Composite Design) will be used to carry out the experiments. Statistical methods will be used to estimate relation between output parameters and input parameters. Optimization of input parameters will be carried out by using principal component analysis. This method is chosen because it can perform analysis of more than one factor at a same time while reducing number of experiment which indirectly reduces cost and time in finding optimal parameter.

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Keyword: - *Wire electrical discharge machining (WEDM) , Material removal rate (MRR) and surface roughness (SR) etc….*

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1. INTRODUCTION

1.1 Background

Accompanying the development of mechanical industry, the demands for alloy materials having high hardness, toughness and impact resistance are increasing. Nevertheless, such materials are difficult to be machined by traditional machining methods. Hence, non-traditional machining methods including electrochemical machining, ultrasonic machining, electrical discharging machine (EDM) etc. are applied to machine such difficult to machine materials. Aluminum is a metal having low density hence it has ability to resist corrosion due to passivation. The various Structural components from the aluminum metal are widely used in aerospace industry and other areas of transportation and structural materials. For fulfilling the demands of parts machining various newly developed machining methods has been introduced. Wire electrical discharge machining (WEDM) is one of them. It has the capabilities to machine parts by wire tool of diameter 250 μm and energy pulse generator (1–10 μJ per pulse). Having the advantages of non-contact machining, high efficiency and low cost, WEDM is an excellent process for machining.

The material removal protocols for both EDM and WEDM are identical but the functional characteristics are different. Mainly, WEDM requires a thin wire for continuously feeding through the work piece by a microprocessor based control system which supports the various complex parts such as shapes are machined with better accuracy. Due to such advantages the various kinds of micro shaped holes, micro gears, complex micro parts and dies etc. can be machined with a better performance by WEDM process than other machining process. According to the requirements of the product for industrial use the development of the WEDM machine has been done with the same principle as that of EDM.

Wire electrical discharge machining (WEDM) also known as wire-cut EDM. In this process a thin single brass or copper coated electrode is fed through the work piece which is immersed in the dielectric fluid, mainly deionized water is used as a di electric fluid. The wire-cut types of machines were used in the sixtieth century for the resolution of making tools and dies by hardened steel. The earliest numerical controlled (NC) machines were renovations of punched tape vertical milling machines. The first commercially available NC machine built as a wire-cut EDM machine was manufactured in the USSR in 1967.

WEDM process with a thin wire as an electrode transforms electrical energy to thermal energy for cutting materials. With this process, alloy steel, conductive ceramics and aerospace materials can be machined irrespective to their hardness and toughness. Furthermore, WEDM is capable of producing a fine, precise, corrosion and wear resistant surface. Its broad capabilities have allowed it to encompass the production, aerospace and automotive industries and virtually all areas of conductive material machining. This is because WEDM provides the best alternative or sometimes the only alternative for machining conductive, exotic, high strength and temperature resistive materials, conductive engineering ceramics with the scope of generating intricate shapes and profiles.

WEDM is considered as a unique adoption of the conventional EDM process, which uses an electrode to initialize the sparking process. However, WEDM utilizes a continuously travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05-0.30 mm, which is capable of achieving very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining. WEDM has tremendous potential in its applicability in the present day metal cutting industry for achieving a considerable dimensional accuracy, surface finish and contour generation features of products or parts. Moreover, the cost of wire contributes only 10% of operating cost of WEDM process. The difficulties encountered in the die sinking EDM area voided by WEDM, because complex design tool is replaced by moving conductive wire and relative movement of wire guides.

1.2 Fundamentals of WEDM

Introduction related your research work Wire electrical discharge machining (WEDM) technology has grown tremendously since it was first applied more than 30 years ago. In 1974, D.H. Dulebohn applied the optical line follower system to automatically control the shape of the component strobe machined by the WEDM process. By 1975, its popularity rapidly increased, as the process and its capabilities were better understood by the industry. It was only towards the end of the 1970s, when computer numerical control (CNC) system was initiated into WEDM, which brought about a major evolution of the machining process

The mechanism of metal removal in wire electrical discharge machining mainly involves the removal of material due to melting and vaporization caused by the electric spark discharge generated by a pulsating direct current power supply between the electrodes. In WEDM, negative electrode is a continuously moving wire and the positive electrode is the work piece. The sparks will generate between two closely spaced electrodes under the influence of dielectric liquid. Water is used as dielectric in WEDM, because of its low viscosity and rapid cooling rate.

The applied voltage creates an ionized channel between the nearest points of the work piece and the wire electrodes in the initial stage. In the next stage the actual discharge takes place with heavy flow of current and the resistance of the ionized channel gradually decreases. The high intensity of current continues to further ionize the channel and a powerful magnetic field is generated. This magnetic field compresses the ionized channel and results in localized heating. Even with sparks of very short duration, the temperature of electrodes can locally rise to very high value which is more than the melting point of the work material due to transformation of the kinetic energy of electrons into heat. The high energy density erodes a part of material from both the wire piece by locally melting and vaporizing and thus it is the dominant thermal erosion process.

In the recent years many researchers have attempted to find out the performance characteristics such as material removal rate (MRR), surface roughness (SR) etc. There are many other inter dependence responses to MRR (kerf width, cutting speed) which needs to be optimized for improving performance characteristics of WEDM process which has been challenging task for the research fraternity. Because of the small size of the part, its dimension accuracy becomes more important in part manufacture. In WEDM, the corner errors and kerf variations mainly caused by the wire tool deflection and vibration in the discharge gap are the main factors to influence the machining accuracy. The kerf variations influencing the dimension accuracy of the parts are more important in WEDM.

2. EXPERIMENTAL SET-UP

WEDM machine

The experiments will be carried out on a wire-cut EDM machine (ELEKTRA SPRINTCUT) shown in figure 3.1 of Electronica Machine Tools Ltd. installed at Aditya Engineering works, Waluj, Aurangabad, India.

Fig 2.1: WEDM Machine Tool

2.1 Machine specification

- Design – Fixed column, moving table
- Work table dimensions- 200 x 250 mm
- Max work piece height - 200 mm

- Max w/p weight – 275 kg
- Table travel- 300, 400 mm
- Wire electrode diameter- 0.2 mm
- Dielectric fluid capacity – 250 Liters
- Input power supply - 3 phase, AC 415 V, 50 Hz
- Average Power consumption – 6 to 7 KVA

2.2 Work piece Material

EN31 Alloy Steel stainless steel round rods, EN31 Alloy Steel forging ,sheet,and profile dstrip, Deformed steel,f latsteel ,mould ,steel wire, have all specifications. With DuoNian production experience, strict control EN31 Alloy Steel chemical composition and EN31 Alloy Steel mechanical properties.From casting, forging, steel to hot and cold rolling process, heat treatment, etc, we have the control of professional engineers. We have advanced precision machining equipment, according to the requirements of users machining. in order to achieve the most satisfied with the user requirements.

%C	%Si	%Mn	%S	%P	%Cr
0.90-1.20%	0.35%	0.75%	Max	Max	1.60%

3. DESIGN OF EXPERIMENT

Design of Experiment (DOE) is an efficient experiment planning process that allows the data obtained to be analyzed, valid conclusions to be drawn and objectives to be set. There are two aspects of any experimental problem, the design of experiment and statistical analysis. Experimental design involves planning experiments to obtain the maximum amount of information from available resources.

DOE is used to determine the appropriate number of tests and the experimental conditions necessary to obtain the desired goal of analyzing which factor of the process influences the response variables. The most common design consists of running the test with all the possible combinations of variables at predetermined levels.

A well-planned design of experiment can substantially reduce the number of experiments and for this reason a small CCD with five levels was selected to develop the first order and second order models. In the present investigation, experiments were performed on the basis of the Design of Experiments (DOE) technique. The design chosen was full factorial design 2^3 with 8 cube point,4 center point in cube,6 axial point and 2 center point in axial.

Response surface methodology (RSM) is a collection of mathematical and statistical methods to evaluate relationships between a group of quantitative independent variables and one or more responses. The RSM enables to evaluate operation variables that may or may not have significant effect in the main response. The central composite design, CCD, is used to build a second order experimental model. CCD is composed of a factorial design, a set of central points, and axial points equidistant to the center point.

The factorial design component of CCD is of the class 2*k* factorial where *k* represents the number of relevant factors or variables. Each of the variables is taken at two levels meaning that each variable has a low and high numeric value. A coded numeric value of -1 and +1 is assigned to represent the variable’s low and high values. The geometric representation of a factorial is a cube in which each corner represents an interaction of the factors. In this perspective, 3 processing variables are selected to determine their significance in the final response.

The axial component of CCD refers to the points that are equidistant from the center of the cube formed for the factorial design. A spherical design is obtained in the reason that there is an equal variance from the center to all the points in the sphere. In consequence, there is a positive axial value (+a) and a negative axial value (-a). The axial points add two more levels in each variable. The a value is calculated from the equation a = (ni)1/4. Where, ni represent the number of interactions obtained from the factorial design. The central point component in the CCD is the average of the high and low values determined in the factorial design. The central point or zero point may be defined as the region where the optimal conditions are supposedly met. The purpose of adding center points:

- To provide a measure of process stability and inherent variability.
- To check for curvature.

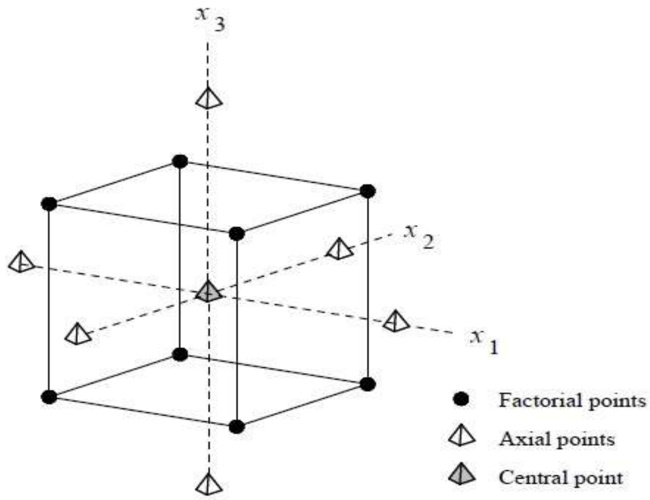

Fig No 4.1: CCD showing 8 factorial points, 6 axial points and 6 center points used For experimentation.

The RMS allows the introduction of blocks that facilitate the accomplishment of experiments. Blocking is justified based on the physical and time limitations to run experiments. However, blocking may have some effects over the final response. If the estimations of the independent and interaction effects of the selected variables are not affected by blocking, the inclusion of blocks in the experimental design is justified. The selection of variables for the analysis using RSM is completed in order to determine which factor may or may not have an important effect in the final response.

3.1 Selected input and output process parameters:

In electrical discharge machining there are lot many process parameters which affects machining like dielectric medium, tool material, supply voltage, electrode type, inter electrode gap, surface roughness of tool material, duty factor etc. Considering the study of previous researchers in the field of WEDM which are mentioned in literature survey, following input process parameters are selected to carry out the experiments.
Input process parameters:

1. Current
2. Voltage
3. Pulse-on time

Output process parameters:

1. Material removal rate
2. Surface roughness

3.2 Selection of levels for input parameters

The working ranges of all process variables selected had to be determined to fix their levels and to develop the design matrix. This is achieved with the assistance of trial runs carried out by varying one of the process variables while keeping the rest of them at constant value. A large number of trial runs have been conducted at different machining parameters. In the current research work the effects of three predictor variables, namely: Current, voltage and Pulse on time were then coded, the upper limit of a factor was coded as +1 and the lower limit as −1. The selected process parameters of the experiment with their limits, units and notations, are given in Table 3.1

Table 3.1: Levels of Parameters

PARAMETER	LEVEL		
	-1	0	1
Current	1.5	2	2.5
Voltage	22	24	26
Pulse on	117	118	119

4. CONCLUSIONS

In this work, experimental investigation will be reported for Wire Electric Discharge Machining on EN-31 an overview of the principle of WEDM, its Experimental set-up and machining process is discussed. The report focuses on problem related to Wire Electric Discharge machining of hard to cut metal with copper electrode. Optimization will be carried out, for stable machining condition.

- Significant parameters affecting the machining performance will be determined through experiments.
- Effect of current, voltage and pulse on time will be studied on material removal rate and surface roughness.
- Mathematical models will be established relating the input parameters to the responses by regression analysis.
- Optimal parameters setting will be obtained so that the machine can work consistently for a longer duration.

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