

Comparative Analysis of Dry-EDM and Conventional EDM in machining of Hastelloy

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Abstract: Dry EDM may be a modification of the traditional electrical discharge machining (EDM) process during which the liquid dielectric is replaced by a gaseous medium. High velocity gas is supplied through it into the discharge gap. The flow of high velocity gas into the gap facilitates removal of debris and prevents excessive heating of the tool and work piece at the discharge spots. It's now known that aside from being an environment-friendly process, other advantages of the dry EDM process are low tool wear, lower discharge gap, lower residual stresses, smaller white layer and smaller heat affected zone.[1] Keeping literature review into consideration, during this research, an effort has been made by selecting compressed gas as a dielectric medium, with Hastelloy as a work piece material and copper as a tool electrode. Conventional experiments were also performed. Experiments are performed using Taguchi DoE orthogonal array to watch and analysis the consequences of various process parameters to optimize the response variables like material removal rate (MRR) and gear wear rate (TWR).

Keywords: EDM, DRY EDM, MRR, TWR

1. Introduction

Cleaner production has become a worldwide topic thanks to global environmental problems caused by the consumption of natural resources and therefore the pollution resulting from the assembly of technical products. These have led to increasing political pressure and stronger regulations being applied to both the users and makers of such products. Sustainable development initiatives were well defined and implemented on the political level, but there was a severe lack of implementation practices to bridge the gap between science, policy-making, and implementation. Adopting sustainable manufacturing practices offer the likelihood for 'difficult to machine' materials machining companies to enhance their economic and environmental performance simultaneously.

The corrosion-resistant Hastelloy alloys are widely employed by the chemical processing industries. The necessity for reliable performance results in their acceptance and growth within the areas of geothermal, solar power, oil and gas and pharmaceutical. The advantages of Hastelloy process equipment include high resistance to uniform attack, outstanding localized corrosion resistance, excellent stress corrosion cracking resistance, and simple welding and fabrication. The fabric is difficult to machine using the normal machining methods, Electric discharge machining of Hastelloy is that the widely used energy-based technique to advance and gain favour as an alternate to traditional machining methods. The low MRR always restricts the appliance range of this method. Several researchers have tried to enhance the MRR of EDM of Hastelloy, like combined with ultrasonic machining and developed a replacement electrode, but the effect wasn't obvious. A high-speed dry EDM was proposed in our previous study, which used non-polluting air as dielectric. Dry machining is taken into account because the best method to eliminate the utilization of cutting fluids in manufacturing enterprises and thus reduce the machining costs and ecological hazards. The MRR of AISI 304 chrome steel during this promising dry machining method might be as high as 5162 mm³/min, which improved the MRR by 2nd to 3rd order of magnitude compared thereupon of conventional dry EDM.

2. Literature Review

Kunieda and Yoshida experiments air as a dielectric for EDM machining. In these experiments steel used as a work piece, and electrode material is copper and dielectric medium is compressed gas. Therein they conclude MRR is lower with tool electrode as a positive polarity compared with the negative polarity, during this polarity of the tool electrode is positive MRR is higher, within the case of EDM during a liquid. In these machining characteristics between EDM in air with a negative tool electrode and EDM in oil with a positive tool electrode is compared. When the polarity of the tool electrode is negative the tool electrode wear ratio is additionally much lower compared with the polarity of the tool electrode is positive.[2]

Kunieda et al. controlling the discharge gap distance to enhance the dry EDM characteristics by employing a piezoelectric actuator, during this compressed gas is use as a dielectric, copper-tungsten pipe of 1mm in diameter as tool electrode and steel as a piece, during this research conclude that with increasing gain of the driving force for the piezoelectric actuator, the probability of short-circuiting decreases, by leading to considerable increase of the MRR. TWR was 0.29%, and it took 43 minutes to machine the grooves with a depth of 0.8mm. Without the piezoelectric servo, the tool wear ratio was 1.3 times higher and therefore the machining took 1.7 times longer.[3]

Tao et al. experimentally reported the dry and near dry EDM process. In near dry EDM two phase gas-liquid mixture was used because the dielectric medium within the 25-1 fractional factorial designed experiments the effect of gap voltage, circuit voltage, discharge current, pulse interval and pulse duration were investigated at constant values of pressure and gear. For higher MRR with rough machining, copper tool and oxygen gas dielectric with a high current and low pulse off time were suitable. Using kerosene-air mixture as dielectric the very best material removal rates (MRR) of 1.8 mm³/min. [4]

Govindan and Joshi investigated on performance of dry EDM using slotted electrodes during this copper used as tool electrode, work piece is SS304 and dielectric medium is oxygen. By using different number of slots on electrode and eventually concluded that four slots as optimum number of slots for max material removal rate (MRR). In this 1.497 mm³/min is that the highest average material removal rate is recorded. Using the electrodes with peripheral slots improve the flush debris particles thanks to this increasing the fabric removal rate (MRR).[5]

Govindan and Joshi reported on experimental characterization of fabric removal in dry discharge drilling during this tool electrode material is employed as a copper, work piece material is steel and dielectric medium is oxygen. There are two sorts of tool wear rate (TWR) one is erosion of electrode material and second is deposition of fabric on the electrode. When oxygen pressure at 94.5%, radial clearance at 88.5% and spindle speed at 88% then the minimum tool wear rate is occurred. In their experiment tool wear rate (TWR) was near on the brink of zero and none of the input parameter influencing tool wear rate (TWR).[6]

Grzegorz Skrabalak and Jerzy Kozak study on dry electrical discharge machining (DEDM). In this, compared of surface roughness during dry electrical discharge machining (DEDM) milling with single hole 2-channel electrodes. In this comparison of green machining method with kerosene based EDM milling. In this also presented basic characteristic of the electrical discharge machining (DEDM) milling process.[7]

3.Process Parameters

The process parameters which will influence the experiment of optimizing while machining of the Super alloy is 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 (μs) 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.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.

3.1.EDM 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. 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 as given below.

$$MRR = \frac{W_i - w_f}{\rho w t} \quad \text{mm}^3/\text{min}$$

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 ρ_w is the density of work piece material.

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

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

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 machining time in minutes and ρ_e is the density of electrode.

4.Objective

The objective of this research is to study the effect of different process parameters on Material removal rate and tool wear rate of conventional as well as dry-EDM.

The quality of EDM is dependent on various process parameters. If any of the process parameters is changed, it directly affects the quality of EDM. Hence in this project we varied three process parameters namely current (A), pulse on time (ton) and duty factor (%).

5.Experimental Detail

5.1. Machine Specifications

Sr. No	Description	SZNC 20-4025	Unit
1	Work Tank Dimensions	600 x 400 x 300	Mm
2	Table size	400x250	Mm
3	Z-Axis travel with ball screw	200	Mm
4	X and Y-Axis travel with ball screw	150	Mm
5	Max. Job Height	165	Mm
6	Max. Job Weight	100	Kgs
7	Max. Electrode weight	80	Kgs
8	Best MRR (Cu to Steel)	140	mm ³
9	Min. Electrode Wear	0.1	%
10	Best Surface Finish	0.5	Ra
11	No. Of Filters	1	No.
12	Dielectric tank capacity	200	Litres



Fig 1: EDM Machine

5.2. Workpiece Material and Electrode Selection

The experiments were conducted on Hastelloy. The workpiece used for experiment was 60 mm in diameter and 10mm in thickness. The material was cut into slabs using wire EDM.

Material composition

Element	Composition %
Nickel	56
Chromium	22
Molybdenum	13
Tungsten	3
Iron (Fe)	3
Silicon	0.08
Manganese	0.5
Carbon	0.01
Vanadium	0.35
Copper	0.5

Dimension of work piece was 60mm in diameter and 10mm in thickness. The electrode used was of copper of dimension 20mm*20mm*5mm.



Fig. 2: Workpiece



Fig. 3: Tool

5.3. Design of Experiment

After carrying out the literature survey we carried a lot of screening experiments to get a range of each process parameters

The experiments are designed based on Taguchi L₉ orthogonal array for different parameters such as three levels of current, pulse on time and duty factor. The process parameter and their levels are shown in Table.

Input parameter	Level		
	1	2	3
Current I(A)	5	10	15
Ton(μs)	10	30	50
Duty Factor (%)	40	60	80

Expt. No.	Current (A)	Ton (μs)	Duty Factor (%)
1	5	10	40

2	5	30	60
3	5	50	80
4	10	10	40
5	10	30	80
6	10	50	60
7	15	10	80
8	15	30	40
9	15	50	60

6.Experimental Results and Analysis

Experiments done on conventional as well as dry EDM by using L9 orthogonal array. The machine voltage was set to 40V and using compressed air at 2 bar constants for dry EDM.

From results we can see that MRR increase as Ton, current and duty factor increase. Current is the most significant factor in the process.

This happens due to the number of electrons continue sparking on the workpiece surface on every cycle of discharge due to this more material is eroding from the work piece per discharge.



Fig. 4: Machined Workpiece Fig. 5: Machining

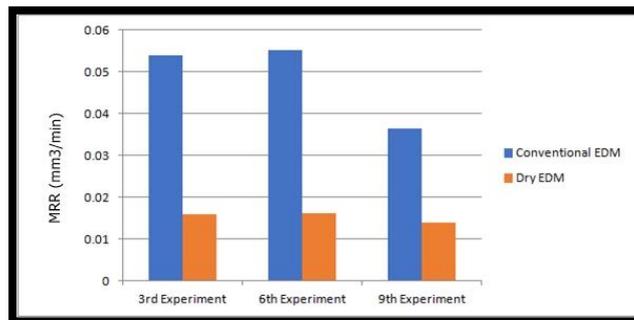


Fig. 6: MRR comparison

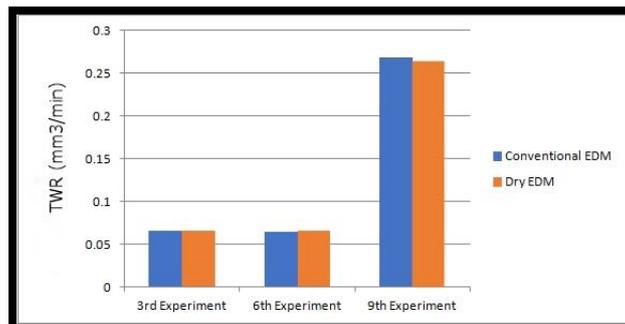


Fig. 7: TWR comparison

From the graph of MRR it is observed that MRR of conventional is more as compared to Dry-EDM. This is due to difficulty in flushing. The debris stay accumulated in same place and results in lower MRR.

As the current increases decreases the tool wear rate (TWR) because maximum amount of discharge energy is used to remove the material from work piece due to this the eroded material deposit on the tool.

7. Conclusion

1. In this research, the effect of process parameters on the response variables such as Material Removal Rate (MRR) Tool Wear Rate (TWR) of Hastelloy was investigated experimentally in conventional and dry EDM.
2. Dry-EDM shows lower MRR as compared to conventional EDM due to difficulty in flushing. TWR decreases in Dry-EDM

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