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Research Article

Performance study of different EDM Electrode Materials for machining of honeycomb cavities of plastic injection molds

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Abstract

Electro Discharge Machining (EDM) is an extremely prominent machining process among newly developed non - traditional machining techniques for "difficult to machine" conducting materials such as heat treated tool steels, composites etc. In EDM, the material removal of the electrode is achieved through high frequency sparks between the tool and the work-piece immersed into the dielectric. The Material Removal Rate (MRR), Tool Wear Rate (TWR) and surface integrity are some of the important performance attributes of the EDM process. This is widely used in machining intricate cavities in Aluminum HPDC Dies, Tyre mold manufacturing and Plastic Injection mold manufacturing. In Plastic injection mold manufacturing, especially for machining narrow cavities of honeycomb structures, the tool wears faster and machining becomes costly. This study compares performance of three materials viz. Copper, Graphite and Copper impregnated Graphite used as EDM electrodes and evaluates their performances based in lower Tool Wear Rates (TWR)

Keywords: *EDM, Copper impregnated Graphite, TWR.*

Introduction

Overview on EDM

In this technological era, manufacturing industries are facing challenges from such advanced difficult- to-machine materials, viz. super alloys, ceramics and composites and stringent design requirements (high surface quality, high precision, high strength, complex shapes, high bending stiffness, good damping capacity, low thermal expansion and better fatigue characteristics) and machining costs. There is a growing trend to use lightweight and compact mechanical components in recent years; therefore, there has been an increased interest in the advanced materials in modern day industries. The new concept of manufacturing uses non-conventional energy sources like sound, light, mechanical, chemical, electrical, electrons and ions. The machining processes are non-conventional in the sense that they do not employ traditional tools for metal removal and instead they directly use other forms of energy. For the last few years, EDM has been used to machine advanced materials with desired shape, size and required accuracy.

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EDM is a non- conventional machining process, where electrically conductive materials are machined by using precisely controlled sparks that occur between an electrode and a work-piece in the presence of a dielectric fluid. It uses thermoelectric energy sources for machining extremely low machinability materials; complicated intrinsic- extrinsic shaped jobs regardless of hardness have been its distinguishing characteristics. Machining of any electrically conductive material irrespective of its hardness, by the application of thermal energy is one of the prime advantages of the EDM process.

EDM process parameters

Different EDM machines have different sets of parameters due to their designs. To perform an efficient machining, one should have to identify important process parameters which influence the responses which are described below. The complete set of parameters is machine dependent. The machining parameter can be categorized into;
Input /process parameters:

The parameters are voltage (V), discharge current (Ip), pulse- on time (Ton), pulse-off time (Tof f), duty factor (τ), flushing pressure (F p), work-piece material, tool material, inter-electrode gap (IEG), Lift Time (Tup), Work Time (Tw) and polarity (p) which affects the performance of machining process.

Response /performance measures

The parameters are MRR, TWR, SR and Surface integrity, used to evaluate the machining process in both qualitative and quantitative terms.

Experiment

Deep and narrow slots are the processing objects studied in this paper. In order to facilitate a large number of repeated experiments, the size of the structure is designed as 20 × 1 × 20 (length × width × depth \mm). Ecocut EDM machine tool (Electronica machine tools ltd) was used as the experimental platform. EDM oil (EDM-3, Mobile®) is used as the dielectric. The tool electrode is made of EX-60 EDM graphite produced by IBIDEN. The workpiece is made of AISI-D2 die steel. The finished slots were cut using WEDM.

The height or depth of the electrode was measured using a height gauge each time the operation was completed.

Input Parameters to vary:

1. Pulse Width (ON): While the machine had a capacity to give ON time variation from 70 µs to 180 µs, we took only 180 µs as Yuchao Jia et al.[10] have investigated and concluded that within a range of 90µs to 180µs range, 180 µs gives best MRR and EWR
2. Peak Current (IP)
3. Electrode Material (Copper, Graphite and Copper Impregnated Graphite)

In line with the results and conclusions by Yuchao Jia[10] we opted to vary only Electrode material and use other influential parameters like

In the experimental work, orthogonal design was used first to study the material removal rate (abbreviated as MRR) and relative tool wear rate (abbreviated as TWR) of different parameter combinations. Then through a fractional factorial experiment, the specific effects of the main factors on the tool wear behavior were analyzed.

The main factors affecting the relative tool wear rate (abbreviated as TWR) were selected from the pulse width (ON), peak current (IP), servo reference voltage (SV), pulse duty ratio (Ratio) and machining time of jump motion (DN). The range of available parameters was determined based on machine performance. Table 1 shows the parameter range in which a 20mm × 1mm ×20mm narrow slot can be processed stably.

Different tool wear behavior was distinguished by fractional factorial experiments. Since this project focuses on the range of parameters showing different wear patterns, the experimental conditions are selected based on their actual performance. Therefore, the experimental conditions are not strictly equidistant. During the experiment, supplementary experiments were selectively added between near zero TWR conditions to increase the accuracy of the result curve.

Design of Experiment

Taguchi Method Design of Experiments

The general steps involved in the Taguchi Method are as follows:

1. Define the process objective, or more specifically, a target value for a performance measure of the process. This may be a flow rate, temperature, etc. The target of a process may also be a minimum or maximum; for example, the goal may be to maximize the output flow rate. The deviation in the performance characteristic from the target value is used to define the loss function for the process.
2. Determine the design parameters affecting the process. Parameters are variables within the process that affect the performance measure such as temperatures, pressures, etc. that can be easily controlled. The number of levels that the parameters should be varied at must be specified. For example, a temperature might be varied to a low and high value of 40 C and 80 C. Increasing the number of levels to vary a parameter increases the number of experiments to be conducted.
3. Create orthogonal arrays for the parameter design indicating the number of and conditions for each experiment. The selection of orthogonal arrays is based on the number of parameters and the levels of variation for each parameter, and will be expounded below.
4. Conduct the experiments indicated in the completed array to collect data on the effect on the performance measure.
5. Complete data analysis to determine the effect of the different parameters on the performance measure.

Considering 2 input parameters viz. IP and Electrode Material and 3 levels for each parameter, we can follow the L12 array wherein we can take 12 observations to conclude the experiment.

Experiment Number	Column										
	1	2	3	4	5	6	7	8	9	10	11
1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	2	2	2	2	2	2
3	1	1	2	2	2	1	1	1	2	2	2
4	1	2	1	2	2	1	2	2	1	1	2
5	1	2	2	1	2	2	1	2	1	2	1
6	1	2	2	2	1	2	2	1	2	1	1
7	2	1	2	2	1	1	2	2	1	2	1
8	2	1	2	1	2	2	2	1	1	1	2
9	2	1	1	2	2	2	1	2	2	1	1
10	2	2	2	1	1	1	1	2	2	1	2
11	2	2	1	2	1	2	1	1	1	2	2
12	2	2	1	1	2	1	2	1	2	2	1

Results and Discussion

In line with the experimental design, we conducted 12 trials and have tabulated the results as under.

Sr.	Input Variable						Output Variable	
No.	Electrode Material	IP	Time Taken	MRR	Electrode Errosion	Volume of Electrode eroded	EWR	EW
		A	Hrs	mm3/min	mm	mm3	mm3/min	%
1	Copper	30	1.04	3.2	0.2100	4.200	0.067	2.10
2		40	1.23	2.7	0.2900	5.800	0.079	2.91
3		50	0.53	6.3	0.3200	6.400	0.201	3.19
4		60	0.43	7.8	0.3230	6.460	0.250	3.21
5	Graphite	30	0.93	3.6	0.1930	3.860	0.069	1.92
6		40	1.08	3.1	0.2800	5.600	0.086	2.79
7		50	0.49	6.8	0.2880	5.760	0.196	2.88
8		60	0.42	7.9	0.3050	6.100	0.242	3.06
9	Copper Impregnated Graphite	30	1.1	3.03	0.2516	5.032	0.076	2.516
10		40	1.3	2.56	0.2816	5.632	0.072	2.816
11		50	0.6	5.56	0.3008	6.016	0.167	3.008
12		60	0.51	6.54	0.3106	6.212	0.203	3.106

Conclusion

The observations show that for the given geometry, Graphite has the least of the Electrode Wear Rates than other two materials viz. Copper and Copper impregnated Graphite.

It is also observed that the TWR is least for 30A peak current.

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