APPLICATION OF TAGUCHI AND ANOVA TO OPTIMIZE THE PROCESS PARAMETER OF ELECTROCHEMICAL DEBURRING

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ABSTRACT: Deburring is, to put it simply, a finishing method used in industrial settings and manufacturing environments. The raised particles and shavings that appear when metal blanks are machined are referred to as burrs, and the process by which they are removed is known as deburring. Deburring process with high efficiency and full automation is an extremely difficult task. Electrochemical deburring offers very cost effective and efficient solution. In the present research an electrochemical deburring system with its various sub-systems have been successfully developed and a planned experimental design proposed by Taguchi involves orthogonal array was employed to organise the effects of the main influencing process parameters on deburring rate and change in burr height. Analysis of variance was carried out to analyse the difference and variation among and between groups. The analysis of the experimental results made in the present research can act as a guide in selecting the best combination of input parameters for die steel material.
Key words: ECD,DEBURRING RATE,BURR HEIGHT

I. INTRODUCTION

A burr is defined as a projection of undesired material beyond the desired machined features. Burrs are thin ridges, usually triangular in shape, that develop along the edge of a work piece from various manufacturing operations, e.g. machining, shearing of sheet materials, trimming, forging, casting, etc. Most of the conventional machining processes and also some non-conventional machining process produce burrs. Shapes of the burrs are generally triangular but sometime curly, wedge, circular may be appeared. Elimination of burrs at the machining stage itself is not possible but it can only be minimized by controlling the machining parameters and by selecting proper machining method as far as possible. Burrs formed during machining are the cause of many industrial problems. Burrs can cause many problems during inspection, assembly and automated manufacturing of precision components. They usually reduce the quality of machined parts and can cause interference, jamming and misalignment of parts. Because of their sharpness, they can be a safety hazard to personnel. Burrs may reduce the fatigue life of components and can damage them. Burrs can lead to noisy, unsafe operation in assembled machine parts, produce friction and wear in parts moving relative to each other, short circuit in electrical component and may reduce fatigue life in components. Production efficiency somehow reduces efficiency of production and also increased cost. Conventional deburring processes require time, labour and other associated costs. Automation is the best way through which efficiency can be realized. But is an extremely difficult problem to make a successful deburring process fully automated and thereby achieve high efficiency. Yuming Zhou, Jeffrey J. Derby [1] presented a new formulation for the cathode designproblem in electrochemical machining which is based on a finite element method for solution of the direct problem of anode shape simulation and an optimization approach for cathode shape determination. Analytical solutions of the inverse ECM problem are quite limited in the classes of anode shapes which can be considered, while numerical inverse formulations have been plagued by inaccuracy and convergence difficulties. In-Hyu Choi, Jeong-Du Kim [2] studied about the characteristics of electrochemical deburring, identified through experiments and the main factors, such as electrolytic gap and electrolytic fluid, contributing to the elimination of a burr, were analyzed by the height of the burr. Also the deburring efficiency and electrochemical performance for an internal cross hole were examined for different electrolytic current and deburring conditions. In-Hyu Choi, Jeong-Du Kim [3] developed a mechanism of electrochemical deburring by using electroplated cubic boron nitride (CBN) wheels and its deburring performance is investigated in an internal cross holes perpendicular to a small diameter and long length pipe. The experimental technique used was based on the process of combination of a rotation wheel (CBN) with an electrochemical dissolution involved in deburring inside cross hole. It is observed that literature is lacking to say much about the use of ECD for deburring of external burrs on SS304 material and thus it has been realized that there is an immense need for studying and analyzing the effect of various influencing process parameters of ECD of die steel material in order to achieve the best deburring results. In the present research, a 3 x 3 full factorial design technique was used to study the effect of different main influencing process parameters such as, voltage, initial inter-electrode gap and deburring time on various deburring criteria such as change in burr height and deburring rate for achieving enhanced deburring characteristics.

II. WORKING PRINCIPLE AND FUNDAMENTAL FEATIRES OF ECD

In electrochemical deburring, burrs are removed by concentrating electrolytic dissolution on the desired spot in the material, as in the application of electrochemical machining. Here electrode (tool) is placed close to the work-piece (generally 0.1mm to 0.5mm away). When an electrolyte flows and an electric current passes through the gap, the burr near to the electrode gets dissolved due to the electrochemical action. When a grater current density is induced into the gap between work-piece and electrode, then the dissolution rate of work-piece becomes higher. The dissolution rate is independent of the hardness and other characteristics of the work piece material. Deburring rate is being proportional to the current density. The machining rate can be kept constant irrespective of hardness and the toughness of the workpiece material. In electrochemical deburring, the hardness of the machined surface is not changed after the deburring process. However, careful treatment against electrolytic erosion is needed.

III. EXPERIMENTAL SETUP AND EXPERIMENTAL PROCEDURE

A. Design and Development of the Experimental Setup: The schematic diagram of the developed electrochemical deburring system used in the present research, is shown in Fig.2. Workpiece (die steel) and the deburring tool (copper) are being securely held by a three-jaw chuck and a collet chuck, respectively, with good accuracy. Both the tool and work holding devices are insulated from the main body in order to prevent the main machine body from electric shock and also to focus an electrochemical reaction between tool and workpiece. Electrical power supply for machining operation: Generally alternative current (AC) current has been employed as an input. A rectifier circuit comprise of three phase step down transformer, three phase bridge rectifier to convert AC into DC. The control panel is a 3 Dia bridge type rectifier with manual control on the DC output current 0-300A at any voltage between 0-26V DC. DC Ammeter and DC voltmeter monitor and increase decrease push button is used to control the current and voltage respectively. Power supply for machine drive: Stepper motor is the key drive at different load combination. A 4-phase sequence and suitable stepper motor drive has been used and which should be able to rotate the stepper motor at required speed with adequate torque.

B. Experimental Procedure: A total of nine pieces of work piece were cut from a square bar of DIE STEEL for conducting twenty-seven experimental runs. Burrs were created along the edge of each of these work piece samples with the help of shaping operation. The initial height and the final height of the burr for each work piece were measured using a digital micrometer having a least count of 0.001. The deburring rate was calculated by dividing the change in burr height by the corresponding deburring time elapsed. The electrolyte was pumped into the inter-electrode gap with the help of a centrifugal pump. The deburring voltage and the frequency were adjusted by a DC power supply equipped with inbuilt ammeter, voltmeter and oscilloscope.

IV. EXPERIMENTAL DESIGN

The effect of voltage(V), initial inter-electrode gap(G) and machining time(T) on the change in burr height, deburring rate and peak current during the ECD process of die steel material were studied. Table 1 shows the operating conditions and their descriptions for the ECD process

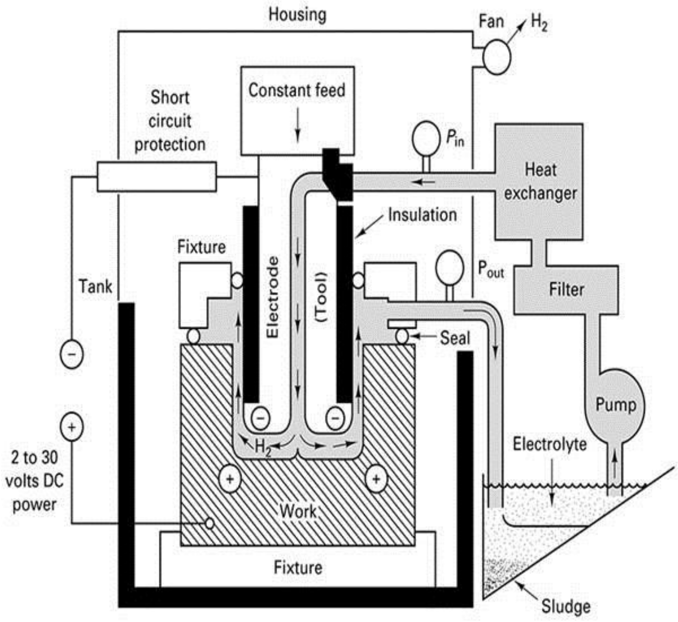


Fig 2. A schematic view of the ECD set up

Deburring voltage,

$X1 = (V - Vo)/\Delta V$ (1)

Initial inter-electrode gap,

$X2 = (G - G0)/\Delta G$ (2)

Deburring time,

$X3 = (T - T0)/\Delta T$ (3)

where, X1, X2 and X3 are the coded values of the variable. V0, G0 and T0 are the values of voltage, initial inter-electrode gap and machining time at zero level (central level) ΔV, ΔG and ΔT are the intervals of variation in V, G and T respectively.

Table 1: Working conditions for the ECD process

(Working conditions)	Values / Descriptions
Workpiece material	Die steel
Electrolyte	NaNO3
Electrolyte flow rate	4.5liter/min
Initial burr height	1.2 mm
Frequency	60 Hz
Pulse ON time	80%
Pulse OFF time	20%
Electrolyte concentration	25gm/liter
Deburring voltage	20 - 30volts
Initial inter-electrode gap	1.2 - 1.6mm
Deburring time	2 - 6minute

TABLE 2: FACTORS AND LEVELS

Symbol	Control factor	Level			Unit
		1	2	3	
A	Voltage	20	25	30	volts
B	Gap between tool and burr tip	0.5	0.7	0.9	mm
C	Time	7	8	9	min

TABLE3: ORTHOGONAL ARRAY

Expt. No.	Voltage (volts)	Gap (mm)	Time (min)
1	20	0.5	7
2	25	0.7	7
3	30	0.5	7
4	20	0.9	8
5	25	0.5	8
6	30	0.7	8
7	20	0.7	9
8	25	0.9	9
9	30	0.5	9

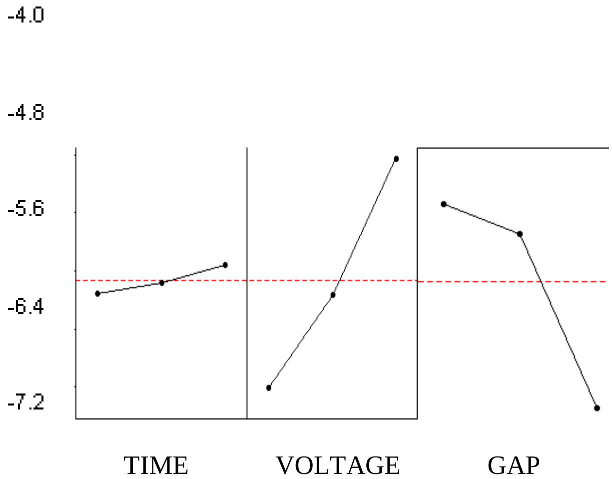
TABLE4: Arrangement of a 3x3 full factorial design used in the present study

Expt. No.	Voltage (volts)	Gap (mm)	Time (min)	Change in burr height (mm)	Deburring rate (mm/min)
1	20	0.5	7	0.442	0.0674
2	25	0.7	7	0.658	0.094
3	30	0.5	7	0.681	0.0971
4	20	0.9	8	0.435	0.0544
5	25	0.5	8	0.760	0.095
6	30	0.7	8	0.683	0.0854
7	20	0.7	9	0.649	0.0721
8	25	0.9	9	0.421	0.0467
9	30	0.5	9	0.872	0.0968

V. RESULTS AND DISCUSSION

A. Effect of the Working Parameters on the Change in Burr Height

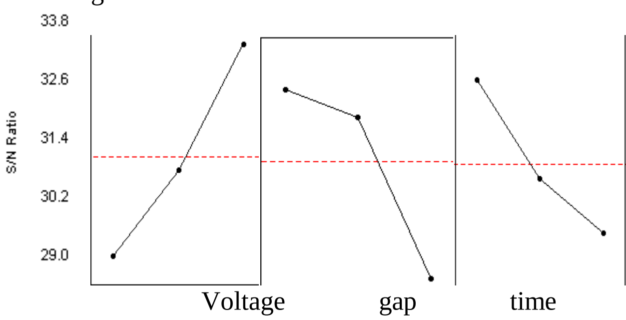
In ECD change in burr height is an important criterion. The effect of initial inter-electrode gap on the change in burr height at various deburring times is represented through Fig. 3. It can be seen that an increase in the initial inter-electrode gap leads to a decrease in the change in burr height (removal height of the burr) at all deburring times and that the removal height of the burr is higher at higher deburring times. Increasing initial inter-electrode gap decreases the current density between the electrodes reducing the total change in burr height. In ECD, it is profitable to keep the inter-electrode gap small, but too small a gap should be avoided as this may cause electric sparks and shorts.



S/N RATIO CURVE FOR BURR HEIGHT

The figure above shows the effect of initial inter-electrode gap on the change in burr height at various deburring voltages. This figure also exhibits similar pattern i.e. the change in burr height decreases with increase in the initial inter-electrode gap at all deburring voltages, From Fig. it can also be seen that for a given initial inter electrode gap, the change in burr height is more at higher voltages which is because of an increase in the current, flowing through the inter-electrode gap, due to increase in the voltage.

B. Effect of the Working Parameters on the Deburring Rate



S/N RATIO CURVE FOR DEBURRING RATE

The above figure exhibits the effect of deburring time on the deburring rate at various initial inter-electrode gaps. It is found that the deburring rate decreases with time and that the deburring rate is higher at lower initial inter-electrode gaps. The increase in removal height of the burr with time is quite understandable because as machining is continued for longer duration, more amount of burr gets removed. However, the rate of burr removal (deburring rate) decreases with increase in the deburring time

C. Analysis of Variance (ANOVA)
An analysis of variance was performed on the experimental results. In the present study, the experiment comprised of three factors (voltage), (initial inter-electrode gap), (deburring time)

ANOVA analysis for deburring rate. (NaNO3)

Source	DOF	SS	MS	% of contribution	F
Voltage	2	0.05473	0.363	50.26	1.79
Gap between tool and burr tip	2	0.05164	0.327	39.19	1.53
Time	2	0.00419	0.225	9.62	0.31
Error	0	-			
Total	8	0.13125			
Error	8	0.13125	0.0157		

Analysis of variance (ANOVA) for change in burr height

source	DOF	SS	MS	% of contribution	F
Voltage	2	0.777	0.319	55.24	1.42
Gap between tool and burr tip	2	0.0538	0.0436	42.37	1.25
Time	2	0.0031	0.0019	2.17	
Error	0	0	-	-	
Total	8	0.1438	-	-	
Error	8	0.1438	0.0239		

VI. CONCLUSIONS

Based on the present study and experimental analysis of electrochemical deburring (ECD) on die-steel material, the following general conclusions may be drawn:
i) Electrochemical deburring (ECD) is a very effective and useful process of deburring which requires very less operation time and also causes no side effect as compared to other deburring processes,
ii) From the fundamental study of Electrochemical deburring process it can be said that burrs are removed by concentrating electrolytic dissolution on the desired spot on the workpiece, as in the application of electrochemical machining,
iii) The effective utilization of electrochemical deburring in modern manufacturing industry to achieve higher deburring rate with greater accuracy especially for the hard to machine advanced materials such as die steel, etc, there is need of proper selection of electrolyte and combination of different process parameters,
iv) An experimental analysis for change in burr height and deburring rate based on Taguchi method and subsequent ANOVA test has been successfully used to optimize the process i.e.voltage, machining time and gap between tool and burr tip with NaNO3 electrolyte,
v) Experimental investigation based on Taguchi method and analysis of the results reveal that the machining parameters used in the present set of research i.e. voltage, gap, and machining time with NaNO3 electrolyte voltage and gap have got main effects on change in burr height and deburring rate as exhibited through the graphical representations. This investigation also can evaluate the voltage, gap and machining time where burr removal rate is high.

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