OPTIMIZATION OF PROCESS PARAMETERS IN ELECTROCHEMICAL DISCHARGE MICROMACHINING (ECDM)

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Abstract:Micro Machining of advanced engineering materialsisalwaysa difficult process. Inthis paper we are discussing the details of ECDMdone onPolypropeleneto identify the effect of process parameters such as pulse voltage, electrolyte concentration and type of electrolyte on Material Removal Rate (MRR) and Diameteral Overcut (DOC).The selection of the electrolyte for a micro ECDM process is very much important since type and concentration determines the electrochemical reaction. To carry out the experiment, aqueous NaOH, HCl, NaCl solutions were used as electrolytes due to its higher electrical conductivity which allows it to achieve a faster rate of gas bubble generation due to an increased rate of chemical reactions. The electrolyte concentrations were varied among 10, 20 and 30 wt. %. The flow of electrolyte was not considered because it removes the gas bubbles generated during machining operation, resulting in weak sparking and low material removal. The optimal voltage range was between40, 45 and 50V. The electrodes were both made of stainless steel.

Keywords - Pulse Voltage, Electrolyte, Material Removal Rate (MRR) andDiameteral Overcut (DOC).

1 INTRODUCTION

One of the latest hybrid micromachining techniques developed is Electrochemical Discharge machining (ECDM). ECDM is a non-traditional machining process that involves high-temperature melting assisted by accelerated chemical etching. The electrochemical discharge machining (ECDM) process is a complex physical–chemical system, where workpiece material is removed by an anodic dissolution of the material and also by electrical sparks that occur between the working surfaces of the electrode tool and of the electrode piece. The electrical discharges assure a chain of micro explosions in the workpiece surface layer; thus, micro quantities of workpiece materials are removed. It is mainly used for micro machining and scribing hard and brittle, non-conductive materials

2. MATERIAL REMOVAL MECHANISM

Several processes may contribute to the material removal, including Melting and vaporization due to electrochemical discharges, high-temperature etching, differential expansion of constituents and weathering, random thermal stresses and micro crackingand mechanical shock due to expanding gases and electrolyte movement. It is commonly admitted that local heating of the work piece by the electrochemical discharges is the reason why machining occurs. Depending on the material the work piece is made of, material removal is achieved by melting (and maybe even vaporization) or high-temperature etching. Combination of both mechanisms is possible as well.

3 ECDM PROCESS PARAMETERS

The main process parameters which were selected are,

INPUT PARAMETERS:

- Voltage (V)
- Concentration (%wt.)
- Type of electrolyte (%)

OUTPUT PARAMETERS:

- Material Removal Rate MRR (mg/min)
- Diameteral Overcut DOC (mm)
- Heat Affected Zone HAZ (From optical microscope images)

4 EXPERIMENTAL DETAILS

Micro machining is done with stainless steel wires of 0.4mm diameter as tool, which is kept at an initial gap of 0.2mm from the workpiece surface. Micro holes are machined on polypropyleneworkpiece by moving the tool in the vertical direction using the feed mechanism with a feed rate of 5.55×10^{-4}mm/sec. Experiments are carried out using design of experiments based on Taguchi L_9orthogonal array with process parameters as voltage, electrolyte concentration and duty factor which are varied in three levels.

Material removal rate (MRR) and Diametrical Overcut (DOC) are taken as output responses.

MRR is calculated by taking the difference in weight of the specimen with respect to time. DOC is measured as difference in mean diameter of the hole machined to that of tool diameter.

- Workpiece : Polypropelene (1mm thickness)
- Voltage : 50V, 45V, 40V
- Electrodes :
  CATHODE : Stainless Steel wire of 0.38mm
  ANODE : Stainless Steel rod of 10mm diameter
- Electrolyte : Hcl, NaOH, NaCl
- Total time of 3 milliseconds set using function generator
- Concentration of electrolyte is varied among 20%, 25% and 30%

5MEASUREMENT OF MACHINING PERFORMANCE

Experiments were conducted as per designed experimental plan and the performance or responses were measured for each experimental run. The amount of metal removed (MR) was measured by taking difference in weight of the specimen before machining weight (W_1) and after machining weight (W_2) The MRR can be evaluated as;

$$\frac{MRR}{T} = \frac{W_1 - W_2}{T}$$

Where,
T - Machining time

W_1 -Before machining weight

W_2 - After machining weight

DIAMETRICAL OVERCUT (DOC)

$$DOC = \frac{DIAMETER\ OF\ TOOL}{MEAN\ DIAMETER\ OF\ THE\ HOLE}$$

Diametrical Overcut is the ratio of diameter of the tool to the mean diameter of the hole.

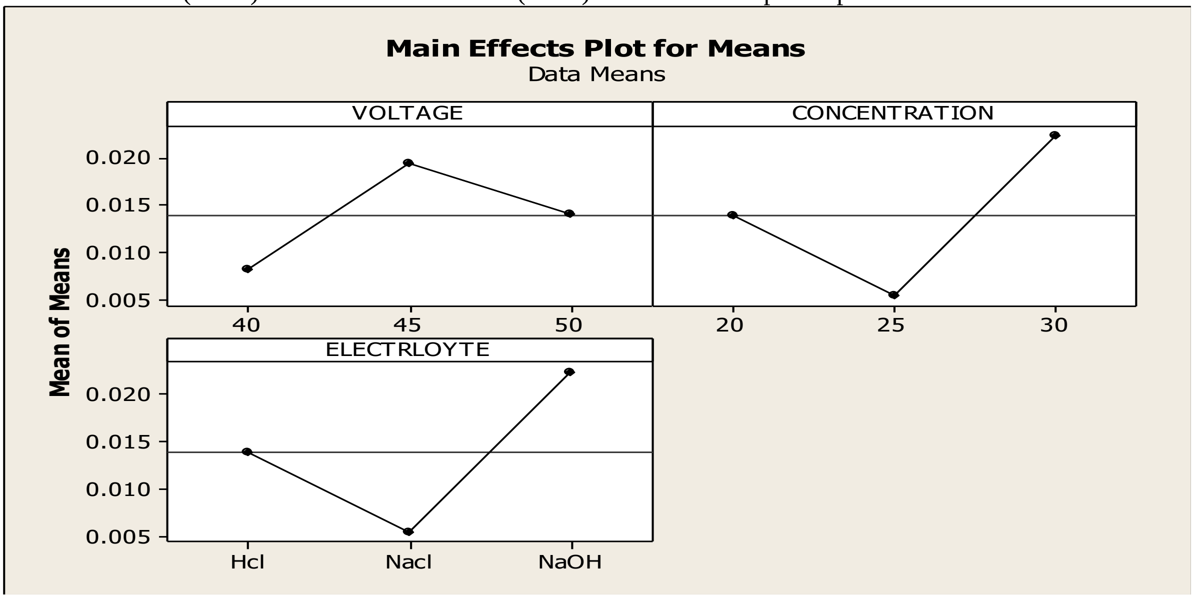
6OBSERVATIONS

Orthogonal array with experimental results

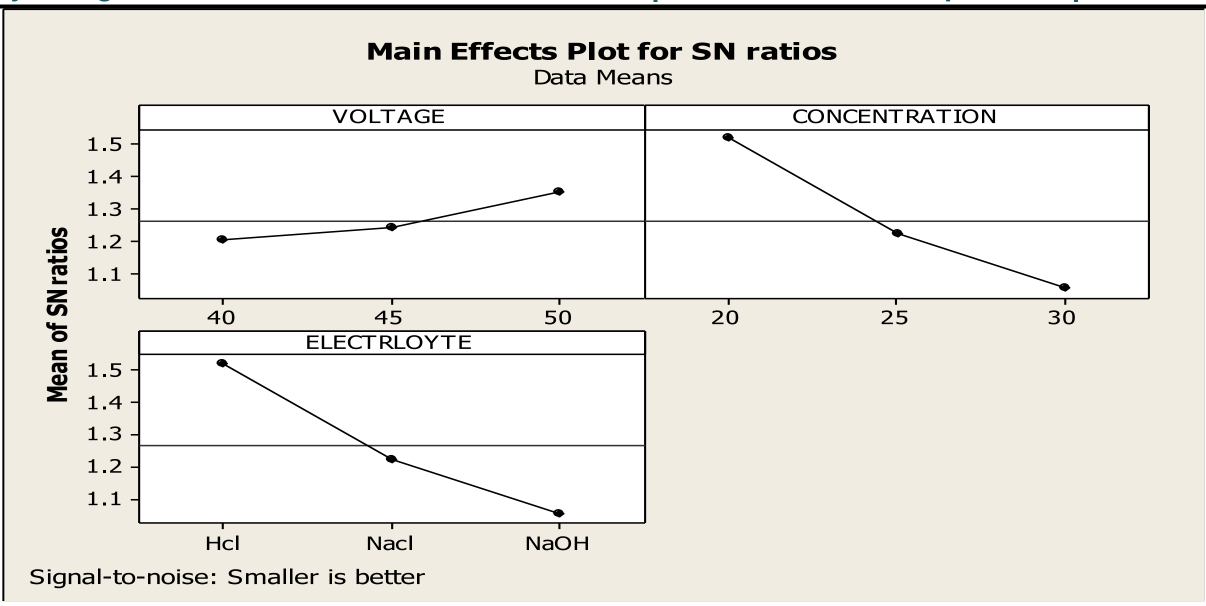
SL NO	VOLTAGE (V)	CONCENTRATION (%)	ELECTRLOYTE	MRR (mg/min)	MEAN DIAMETER (mm)	DOC	SN of MRR	SN of DOC
1	50	30	NaOH	0.0255	0.453	0.8388	31.86919639	1.526831564
2	45	30	NaOH	0.0277	0.419	0.9069	31.15040462	0.848811962
3	40	30	NaOH	0.0138	0.416	0.9134	37.20241827	0.786779855
4	50	20	Hcl	0.0111	0.432	0.8796	39.09354042	1.114295586
5	45	20	Hcl	0.0222	0.481	0.79	33.07294051	2.047458174
6	40	20	Hcl	0.00831	0.446	0.852	21.60797952	1.391208105
7	50	25	Nacl	0.0055	0.447	0.8501	45.19274621	1.410599676
8	45	25	Nacl	0.0083	0.418	0.909	41.61843815	0.828722336
9	40	25	Nacl	0.0027	0.448	0.8482	51.37272472	1.430034638

7. OPTIMIZATION

- Optimization of process parameters were done for maximum MRR and minimum Diametral Overcut
- Experiments are carried out using design of experiments based on Taguchi L_9orthogonal array
- The process parameters were chosen as voltage, electrolyte concentration and type of electrolyte which are varied in three levels
- Material removal rate (MRR) and Diametral Overcut (DOC) are taken as output responses



From the above graphs, we can conclude that for NaOH at 45V and 30% concentrationof the electrolyte gives the maximum MRR



From the above graphs, we can conclude that for NaOH at 40V and 30% concentrationof the electrolyte gives minimum DOC

8. CONCLUSION

ECDM process is done on polypropylene with stainless steel wire tool of diameter 380μm with NaOH, Hcl and NaCl as electrolyte at different concentrations. Micro holes are machined with voltage, concentration of electrolyte and type of electrolytes as process parameters. MRR and DOC are taken as output responses of the process. Main contribution in present work includes:

- An in-house built prototype model of ECDM was developed with stepper motor drive and worm gear feeding mechanism to machine micro hole in polypropylene which can be used for further machining experiments and studies.
- In order to reduce DOC and HAZ, voltage should be at optimum around 40V and electrolyte concentration should be 30% for NaOH as electrolyte with DF of 50%. This will reduce side spark formation thereby reduce HAZ.
- MRR was found to be maximum at 45V with NaOH as electrolyte at 30% concentration

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