Optimization of Process Parameters of Photochemical Machining for MRR, Ra and Undercut by Grey Relational Analysis Method

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Abstract: ***Photochemical machining is one of the least well-known nonconventional machining processes. The objective of present study is to find common optimum values for MRR, Ra and Undercut. Taguchi methodology has been adopted to plan and analyze the experimental results. L16 Orthogonal Array has been selected to conduct experiments. Etching time, etching temperature and etching concentration were chosen as input process variables to study performance in terms of material removal rate surface roughness and undercut. The grey relational analysis method is used to obtain the common optimum values for MRR, Ra and undercut.***

Keywords: Photochemical machining, Etching, Undercut, Surface roughness, Grey relational analysis, Taguchi methodology

1. Introduction

Photo chemical machining is an engineering production technique for the manufacture of burr free and stress free flat metal components by selective chemical etching through a photographically produced mask.

2. Photochemical machining process

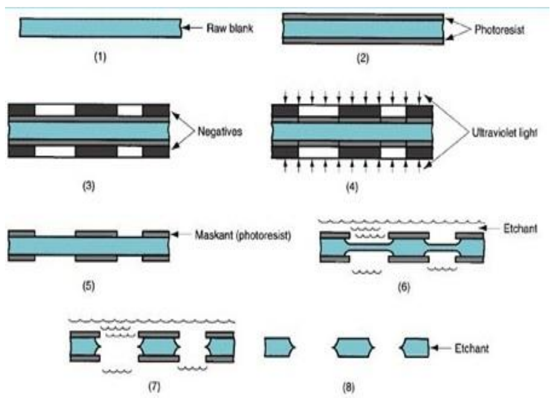


Figure 1: Photochemical Machining

First, the material is cleaned to remove the oil, grease, dust, rust or any substance from the surface of material that would provide good adhesion of the photo resist. The most widely used cleaning method is chemical method due to less damages occurred comparing to mechanical cleaning method. Coating with photo resist (dry or wet) is the next stage of PCM. Then the expose of the prepared photo tool is carried out with UV light. Developing stage is used to remove unexposed areas of the photo resist that is carried out by various chemical liquids. Then the chemical etching operation is carried out in spray etchant machine. The selected etchant for work piece material is heated up to 50-55 °C depending on the spray machine allowance and etchant is sprayed from nozzles onto the work piece surface. Removal of photo resist film from etched work piece surface is the last stage of the PCM.

3. Experimental Set Up

UV Exposure Unit   Etching Unit

Figure 2: Photochemical Machining Setup

The various input parameters and output parameters (response variables) selected for the experimentation are as follows:

1) Input parameters
- Etching Time (t)
- Etching Temperature (T)
- Etching Concentration (C)

2) Output parameters
- Material removal rate (MRR)
- Surface Roughness (Ra)
- Undercut (Uc)

Etchant selection: Ferric Chloride ($FeCl_3$)

Ferric chloride (FeCl3) is the most widely used etchant in the PCM application for etching all iron-based alloys as well as nickel, copper and its alloys, aluminium and its alloys, etc.

Work piece selection: Material SS316L

Type 316L is an extra-low carbon version of Type 316 that minimizes harmful carbide precipitation due to welding. Typical uses include exhaust manifolds, heat exchangers, pharmaceutical and photographic equipment, valve and pump trim, chemical equipment, digesters, tanks, paper and textile processing equipment, parts exposed to marine atmospheres and tubing.

4. Experimental Results

Table 1: Experimental results for Material removal rate, Ra and Undercut for Material SS316L

Exp No	Time min	Temp ^{0}C	Conc gm/lit	MRR mm^3/min	Ra um	Uc mm
1	10	45	600	0.125	0.26	0.0450
2	10	50	700	0.250	0.40	0.0400
3	10	55	800	0.375	0.47	0.1260
4	10	60	900	0.498	0.49	0.1780
5	20	45	700	0.250	0.63	0.1310
6	20	50	600	0.313	0.31	0.2200
7	20	55	900	0.375	0.66	0.1540
8	20	60	800	0.438	0.68	0.1480
9	30	45	800	0.292	0.69	0.1030
10	30	50	900	0.333	0.47	0.2200
11	30	55	600	0.292	0.40	0.1260
12	30	60	700	0.375	0.61	0.1740
13	40	45	900	0.344	0.87	0.3070
14	40	50	800	0.375	0.88	0.2670
15	40	55	700	0.344	0.67	0.2420
16	40	60	600	0.375	0.57	0.2220

5. Regression analysis

The calculated mathematical regression equation of MRR for material SS316L is as follows.

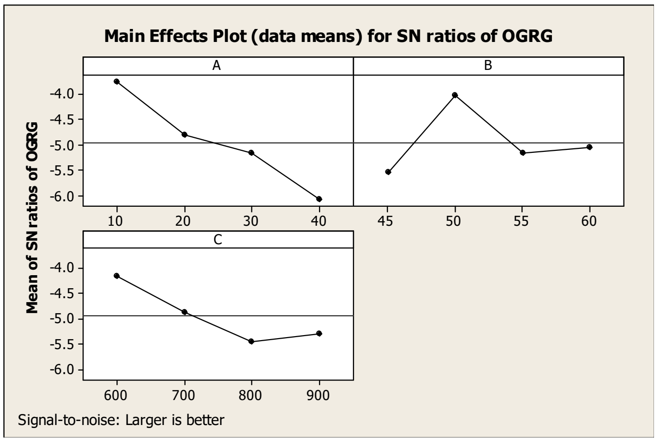
MRR = - 0.557 + 0.00121 Time (min) + 0.0107 Temperature (^{0}c) + 0.000399 concentration (gm/lit)

The calculated mathematical regression equation of Ra for material SS316L is as follows.
Ra = - 0.253 + 0.0100 Time (min) - 0.00080 Temperature (^{0}c) + 0.000815 concentration (gm/lit)

The calculated mathematical regression equation of Undercut for material SS316L is as follows.
Uc = - 0.181 + 0.00479 Time (min) + 0.00154 Temparature (^{0}c) + 0.000199 concentration (gm/lit)

6. Grey Relational Analysis

This approach converts a multiple- response- process optimization problem into a single response optimization situation.



Graph 1: S/N Ratio plot of overall grey relational grade

With the help of the graph 1, optimal parametric combination has been determined. The optimal factor setting becomes t1, T2, C1.

7. Confirmation

Table 2: Results of confirmatory experiment

	Optimal Setting	
	Prediction	Experiment
Level of factors	t1 ,T2 ,c1	t1 ,T2, c1
S/N ratio	-3.2596	-3.4720
Overall Grey Relational Grade	0.6871	0.6705

8. Conclusion

The material removal in PCM process is rather low, where the total volume of a cavity has to be removed. If the PCM is operated at the optimum setting of electrical parameters then this drawback can be minimized.

While machining the material SS316L, the industrialist can directly use the optimum values so that the material removal rate will be maximum and Ra& Uc value will be minimum. The common optimum values for both MRR, Ra& Uc can be easily obtained by the use of grey relational analysis method.

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