Review of Process Parameter Optimization of Photochemical Machining

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Abstract - *Photochemical machining (PCM) is non-conventional machining processes. It employs chemical etching through a photo resist stencil as the method of material removal over selected areas. The control parameters generally considered are the etchant concentration, etching temperature and etching time. The response parameters generally considered for analysis are Undercut (Uc) and the Surface roughness (Ra). The analysis of variance is done to study the effect of various parameters on responses. The optimum values of process parameters may be obtained by using the optimization tools like response surface methodology. In this review paper, the research work done by various researchers is studied.*

Key Words: **Photochemical machining, etching, Undercut, Surface roughness, optimization.**

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.

The development of knowledge of acid attack upon metals is not new its origins lie in antiquity. Legend tells that the ancient Greeks had discovered a fluid, which is referred to as liquid fire that attacked both inorganic and organic materials. However as this was the Bronze Age it is unlikely that they possessed the technology to manufacture such an acidic chemical. The ancient Egyptians etched copper jewelry with citric acid as long ago as 2500BC. The Hohokam people, of what is now Arizona, etched snail shell jewelers with fermented cactus juice around 1000BC. The earliest reference to this process describes an etchant made from common salt, vinegar and charcoal acting through a hand scribed mask of linseed oil paint. Decorative patterns were also etched into swords by means of scribed wax resist. These techniques were adapted and improved by etchers operating in close co-operation with armorer's until, by the seventeenth century; armour had become wholly ceremonial and great works of etched art.

The main advantage is the lack of burrs. During the mid-seventeenth century etching was used for the indelible calibration of measuring instruments and scales such as artillery gunners conversion table etched around 1650. Two developments within the space of forty years in photography laid the foundations for the photo resists we use today. In 1782 John Senebier of Geneva investigated the property of certain resins to become insoluble in turpentine after exposure to sunlight. Inspired by this, Joseph Nicephore Niepce resurrected an ancient Egyptian embalming technique that involved the use of what is now known as Syrian asphalt. This hardens after exposure to several hours of sunlight, into an acid resistant film. However, it took constant experimentation until this development was a success in 1822. The result was a resist that could be photo-polymerized in the exposed areas whereas the unexposed areas could be developed off in a solution of oil of lavender in turpentine. The age of photo etching had arrived. By 1925 the huge daily newspaper industry made large-scale use of printing plates etched in nitric acid solution. By 1927 the use of chemical milling through a rubberized paint mask, which was hand cut around a template, was being used as an engineering production tool.

John Snellman may have been the first to produce flat metal components by photochemical machining of shim stock that was too hard for punching. He innovated the use of cutting lines, or outlines, in the photo resist mask. This ensured even simultaneous etching of every component detail and also his use of tabs secured the parts into the parent metal sheet. He patented the process in 1944 where after it was increasingly used to manufacture shims, springs, stencils, screens.

Within ten years two American companies, the Texas Nameplate Company and the Chance-Vought Aircraft Corporation had taken a considerably refined Snellmans process and renamed it Chemi-Cut. The photo chemical machining process was further developed on both sides of the Atlantic, becoming a production process in the UK in the early 1960s. Development was further accelerated by the introduction in commercial applications of the printed circuit board. The high volumes required for this product saw large strides in development, particularly in the design of etching equipment. These improvements quickly transferred to the photo chemical machining process, leading to the industry.

2. LITERATURE REWIEW

Atul R. Saraf et al, paper presents the machining of Oxygen-Free High Conductivity (OFHC) copper using Photochemical Machining (PCM). Twenty-seven experimental runs base on full factorial (33) Design of Experiments technique were performed. The control parameters considered were the etchant concentration, etching temperature and etching time. The response parameters were Undercut (Uc) and the Surface roughness (Ra). The effects of control parameters on undercut and surface roughness were analyzed using Analysis of Variance (ANOVA) technique and their optimal conditions were evaluated. An optimum surface roughness was observed at an etching temperature of 55 °c, an etching concentration of 600 gm/litre and 15 minutes etchings time. The minimum undercut (Uc) was observed at the etching temperature of 45 °c, etching concentration of 600 gm/litre and 15 minutes etching time. It was found that etchant temperature and etching time are the most significant factors for undercut. [1]

Jinyu Zhang et al, Photochemical machining (PCM) were utilized to fabricate micro textures on carbon steel surfaces in this study. A series of experiments were carried out in the two stages of this process, photolithography and wet chemical etching. In the first stage, the influences of photolithography parameters, including spin coating speed, exposure time and development time, on the patterning of photo resist films were investigated, and the optimum process parameters were found. In the second stage, through a trial and error approach, it has been found that the mixture solution of HNO3:H3PO4:H2O = 8.5%:59.5%:32% (mass percentage) is a suitable etchant for the wet chemical etching of carbon steel. Based on the optimum results, the micro textures of circles and right triangles with different sizes were fabricated on the end faces of carbon steel discs. The variation of the end face profiles and etching depths of the micro textures with the etching time was studied. A prediction model of the geometry of the fabricated micro textures was proposed. Its accuracy was verified by comparison with additional experiment results, and its application scope was also discussed. It makes the precise control of micro texture profiles possible, and facilitates the use of precise micro texture profiles in the hydrodynamic lubrication analysis of textured surfaces. [2]

A.A.G. Bruzzone et al, photochemical machining can satisfy the large demand coming from the microproducts market. The metal etching technologies lack however a precise control over the micro-geometry of surfaces. Metal etching results from diffusive and kinetic phenomena whose relative importance depends on process parameters. The effects of the chemical kinetics on the etching regime and, consequently, on the surface generated by wet-chemical etching need a thorough investigation. This paper reports an experimental assessment of a 2D simulation model of etching, where also the role of reaction products dynamics is considered. Furthermore an experimental analysis of the process parameters on micro-geometry is reported. [3]

H. T. Ting et al, in the last two decades, there has been an enormous surge in interest in ceramic materials and, as a result, there have been significant advances in their development and applications. Their inherent properties, such as capability of operating at temperatures far above metals, high level of hardness and toughness, low coefficient of thermal expansion and high thermal conductivity rendered ceramics to be one of the leading engineering materials. Many research works have been conducted in the past few years on machining of advanced ceramics using different processing methods in order to obtain a better surface roughness, higher material removal rate and improved tool life. Micromachining using chemical etching is one of those methods that do not involve the problem of tool life and direct tool–work piece contact. However, only a few research works have been done on micromachining of ceramics using chemical etching. Hence, study of chemical machining of advanced ceramics is still needed as the process has found wide application in the industry because of its relative low operating costs. In this work, we summarize the recent progresses in machining of different types of advanced ceramics, material processing methods such as wet etching and dry etching, and finally the prospects for control of material removal rate and surface quality in the process of ceramic micromachining. [4]

O. cakir, Chemical etching is employed as micromachining manufacturing process to produce micron-size components. The process applies a strong chemical etchant solution to remove unwanted part in the work piece material. It is basically a corrosion-controlled process. Chemical etching process has a long history and accepted one of the important nontraditional machining processes during the last half century. The method is widely applied to machine geometrically complex parts from thin and flat of any material. It is also used to reduce weight of the work piece materials. In this study, aluminum was machined by well-known chemical etchant, ferric chloride (FeCl3) at different etching temperature. The effects of selected chemical etching parameters on depth of etch and surface finish quality were investigated. It was observed that FeCl3 was very useful chemical etching for aluminum etching. [5]

David M. Allen, paper examines the state of the art of PCM, the PCM Roadmap and the newly-developed products made by PCM especially relevant to Micro engineering, Micro fluidics and Microsystems Technology, economic aspects and current challenges requiring research within the PCM industry. [6]

O. cakir et al, Chemical etching is the controlled dissolution of work piece material by contact with strong chemical solution. The process can be applied to any material. Copper is one of the extensively used engineering materials in the fabrication of microelectronic components, micro engineered structures and precision parts by using chemical etching process. In this study, copper is chemically etched with two different etchants (ferric chloride and cupric chloride) at 50°C. The effects of selected etchants and machining conditions on the depth of etch and surface roughnesses were investigated. The experimental study provided that ferric chloride produced the fastest chemical etch rate, but cupric chloride produced the smoothest surface quality. [7]

Atul R. Saraf, N.D.Misal et al, paper presents the machining of Phosphor bronze using Photochemical Machining (PCM). Twenty-seven experimental runs base on full factorial (33) Design of Experiments technique were performed. The control parameters considered were the etchant concentration, etching temperature and etching time. The response parameter was Undercut (Uc). The effect of control parameters on undercut was analyzed using Analysis of Variance (ANOVA) technique and their optimal conditions were evaluated. The minimum undercut (Uc) was observed at the etching temperature of 400C, etching concentration of 600 gm/litre and 15 minutes etching time. It was found that etchant temperature and etching time are the most significant factors for undercut. [8]

Dr.-Ing. M. Buhlert et al, produced channels on the surface of stainless steel sheets .They used an 800mL rectangular glass basin for photo electro polishing. He filled it with electrolyte and heated the electrolyte basin in a water bath up to 55 °C ±1 °C. The electrolyte was made of chemicals of analytical quality. It consisted of 45 wt./wt.-% phosphoric acid, 35 wt./wt.-% sulphuric acid, dissolved metal (>30 g/l) and water. This solution is capable of giving a smooth and bright surface finish. He used a negative photo resist from HTP based on epoxy acryl ate. The resist was dip-coated and the resist stencil was made by UV-lithography. The advantage of the presented process is that the surface of the removed areas is electro polished. [9]

D.M. Allen1et and P. Jefferies paper describes the implementation of a low-cost, environment-friendly, oxygen-based regeneration system into a commercial etching line. The system has been investigated from both technical and economic viewpoints. It has been demonstrated to be cheaper than alternative regeneration techniques but it is only feasible when etchant parameters are monitored and controlled on-line to prevent the precipitation of ferrous salts. From analysis of the system, it was discovered that the most important parameter to control is the etchant pH. This not only influences the ability to regenerate but also dictates the resultant surface finish of the etched product. [10]

3. CONCLUSION

From the survey of above research papers, it is found that many people have worked for the optimization of process parameters of photochemical machining. They have considered the process parameters like machining time, temperature and concentration of etchant. The responses considered were either material removal rate or surface roughness or undercut. They have found the optimum values for either one or two responses.

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REFERENCES

1] Atul R. Saraf. “OPTIMIZATION OF PHOTOCHEMICAL MACHINING”, International Journal of Engineering Science and Technology (IJEST). ISSN: 0975-5462 Vol. 3 No. 9 September 2011.

2] Jinyu Zhang. “A study of surface texturing of carbon steel by photochemical machining”, Journal of Materials Processing Technology 212 (2012) 2133– 2140.

3] A.A.G. Bruzzone. “An Experimental Evaluation of an Etching Simulation Model for Photochemical Machining”, CIRP Annals - Manufacturing Technology 59 (2010) 255–258.

4] H. T. Ting. “Review of micromachining of ceramics by etching”, Trans. Nonferrous Met. Soc. China 19(2009) s1−s16.

5] O. Cakir. “Chemical etching of aluminum”, journal of materials processing technology 199 (2008) 337–340.

6] David M. Allen. “Photochemical Machining”, CIRP Journal of Manufacturing Systems 2005.

7] O. Cakir. “Chemical etching of Cu-ETP copper”, Journal of Materials Processing Technology 162–163 (2005) 275–279.

8] Atul R. Saraf, N.D.Misal. “Some Investigation on Photochemical Machining of Phosphor Bronze”, Int. Journal of Advances in Science and Technology. Vol.3, No.6, 71-85.

9] Dr.-Ing. M. Buhlert. “PHOTOELECTROPOLISHING OF STAINLESS STEEL”, Fortschritt-Berichte, VDI. Reihe 2, No. 553. VDI-Verlag, Düsseldorf, 2000.

10] D.M. Allen and P. Jefferies,” An Economic, Environment-friendly Oxygen-Hydrochloric Acid Regeneration System for Ferric Chloride Etchants used in Photochemical Machining”, Annals of the CIRP Vol. 55/1/2006.

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