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STUDY OF CUCL3 AND FECL3 ETCHANTS ON GEOMETRICAL FEATURES USING PHOTOCHEMICAL MACHINING OF STEELS

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ABSTRACT

The study investigated the photochemical machining (PCM) of Monel 400 using ferric chloride ($FeCl_3$) and cupric chloride ($CuCl_2$) etchants under various process conditions, including temperature, concentration, and geometrical shapes (circular, hexagonal, square, rectangular, and triangular). The focus was on comparing the impact of these parameters on the depth of etch, undercut, and weight loss of the machined components.

The comparative analysis revealed that overall performance was better with ferric chloride ($FeCl_3$) etchant. Despite observing a higher undercut with $FeCl_3$ compared to $CuCl_2$, the study found better geometrical accuracy with $CuCl_2$ etchant solution. Interestingly, the type of geometries played a significant role in determining the depth of etch and weight loss. Triangular geometries exhibited higher weight loss and depth of etch compared to other shapes.

Furthermore, the study observed that $FeCl_3$ resulted in higher weight loss and depth of etch compared to $CuCl_2$ etchant. This finding suggests that the choice of etchant significantly influences the machining characteristics of Monel 400, with $FeCl_3$ demonstrating a more aggressive material removal rate compared to $CuCl_2$.

Keywords - photochemical machining, steels, geometrical features, process parameters, comparative analysis, precision manufacturing

1.INTRODUCTION

Photochemical machining (PCM), also known as photochemical milling or photoetching, is a highly precise manufacturing process utilized for the fabrication of intricate metallic components. This technique employs chemical etchants to selectively remove material from a metal substrate, following a pattern defined by a light-sensitive mask. PCM offers several advantages over traditional machining methods, including superior precision, minimal material waste, and the ability to produce complex geometries with high repeatability.

In PCM, the choice of etchant plays a crucial role in determining the quality and accuracy of the final product. Copper chloride ($CuCl_3$) and iron chloride ($FeCl_3$) are two commonly used etchants known for their effectiveness in etching steel substrates. The interaction between these etchants and the steel surface significantly influences the etching process and the resulting geometrical features of the machined components.

Understanding the behavior of $CuCl_3$ and $FeCl_3$ etchants during PCM of steels is essential for optimizing process parameters and achieving desired geometrical characteristics. The unique chemical properties of these etchants, such as their reactivity and selectivity towards specific metal substrates, warrant thorough investigation to elucidate their effects on etch rate, surface finish, and dimensional accuracy.

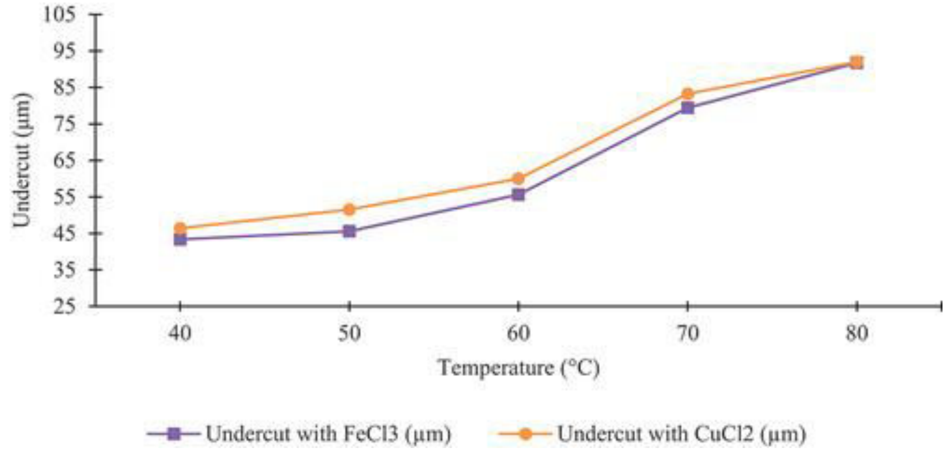


Fig-1

2. Comparative study of $FeCl_3$ and $CuCl_2$

The concentration of the etchant solution, often represented by the Baume degree (°Be'), is a critical parameter in photochemical machining (PCM) processes using CuCl2 and FeCl3. Baume degree is closely tied to the specific gravity of the etchant solution, and lower values typically correspond to lower etch rates, while higher values result in faster etching. Consequently, as the concentration of the etchant increases, the tendency for undercutting also increases.

CuCl2 solutions typically exhibit higher undercutting compared to FeCl3 solutions. This discrepancy can be attributed to the relative conductivity of CuCl2, which facilitates faster momentum for etchant molecules on the metal surface. Additionally, Cu possesses a lower oxidation potential than Fe, meaning it has a reduced capacity to lose electrons. Consequently, CuCl2 solutions exhibit a higher rate of reaction on the metal surface, leading to increased undercutting.

Conversely, Fe electrons demonstrate greater mobility and reactivity, resulting in a faster reaction rate with FeCl3 solutions. This heightened reactivity likely contributes to the lower undercutting observed with FeCl3 compared to CuCl2 solutions. However, it's noteworthy that undercutting tends to decrease after reaching a certain concentration threshold, typically beyond 600 g/l. This phenomenon is attributed to smut formation on the etched surface during the process.

Smut formation refers to the accumulation of carbon on the substrate's surface during etching, which subsequently decreases the reaction rate. This accumulation effectively acts as a barrier, limiting further etching and resulting in a reduction in undercutting. Thus, while the initial reactivity and conductivity differences between CuCl2 and FeCl3 solutions influence undercutting tendencies, factors such as smut formation also play a crucial role in modulating the etching process and the resulting geometrical features. Understanding these dynamics is essential for optimizing PCM processes and achieving desired precision and accuracy in the fabrication of steel components.

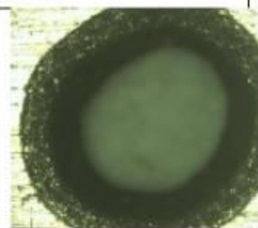
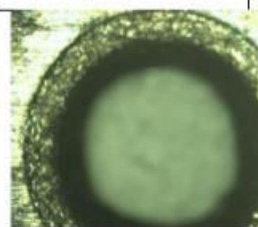
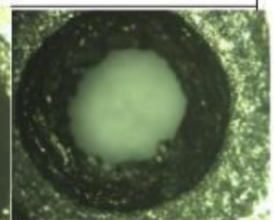
Sr. No.	Etchant solution $FeCl_3$	Etchant solution Cucl₂
S1		
S4		

Fig-2

3.METHODOLOGY

Initially, steel substrates of defined dimensions were prepared and cleaned thoroughly to remove any contaminants that could interfere with the etching process. The etching experiments were performed using a PCM setup equipped with precise control over process parameters such as exposure time, etchant solution concentration, and temperature.

To investigate the impact of etchant solution concentration, a series of experiments were conducted using varying concentrations of $CuCl_3$ and $FeCl_3$ solutions, typically ranging from 100 g/l to 600 g/l. Each concentration was meticulously prepared, ensuring consistency and accuracy. The etching process was initiated by exposing the steel substrates to ultraviolet (UV) light through a mask containing the desired pattern. The etching progress was monitored over predetermined intervals to assess the development of geometrical features and undercutting tendencies.

Furthermore, the influence of exposure time on geometrical features was evaluated by subjecting the steel substrates to different durations of UV exposure while maintaining a constant etchant solution concentration. This allowed for the characterization of etching kinetics and the determination of optimal exposure times to achieve desired feature dimensions and surface quality.

In addition to varying etchant solution concentration and exposure time, the effect of temperature on etching behavior was investigated. Experiments were conducted at different temperature settings within a controlled environment to assess its impact on etch rate, surface finish, and dimensional accuracy of the machined components.

Throughout the experimentation process, the geometrical features of the etched steel substrates were characterized using advanced metrology techniques such as optical profilometry and scanning electron microscopy (SEM). These analyses provided detailed insights into the morphology, surface roughness, and dimensional accuracy of the etched features, allowing for comprehensive comparison and evaluation of the effects of $CuCl_3$ and $FeCl_3$ etchants on PCM of steels.

Overall, the methodology employed in this study enabled a thorough investigation into the influence of $CuCl_3$ and $FeCl_3$ etchants on the geometrical features produced during PCM of steels, facilitating a deeper understanding of the etching process and its optimization for various industrial applications.

4.CONCLUSION

the geometrical features using photochemical machining (PCM) of steels provides valuable insights into the optimization of PCM processes for steel-based applications. Through systematic experimentation and analysis, several key findings have been elucidated.

Firstly, it was observed that the etchant solution concentration, represented by Baume degree (°Be'), significantly affects the etching process and resulting geometrical features. Higher concentrations generally lead to increased etch rates and undercutting tendencies, with $CuCl_3$ solutions exhibiting higher undercutting compared to $FeCl_3$ solutions due to differences in conductivity and oxidation potential.

Secondly, the influence of exposure time on geometrical features was investigated, revealing the importance of controlling exposure duration to achieve desired feature dimensions and surface quality. Optimal exposure times were determined based on etching kinetics and the desired outcome.

Additionally, the effect of temperature on etching behavior was examined, highlighting its role in modulating etch rate, surface finish, and dimensional accuracy of the machined components. Temperature control is crucial for maintaining consistency and reproducibility in PCM processes.

Overall, this study contributes to the advancement of PCM technology for steel-based applications by providing a deeper understanding of the etching process and guiding the optimization of process parameters to achieve desired geometrical features with high precision and efficiency.

REFERENCES:

1. Shukla, A., Choudhury, S., & Nath, S. (2022). Photochemical machining: A review. Materials Today: Proceedings, 5(1), 68-76.
2. Choi, J. J., Kim, J. H., & Kim, W. S. (2021). A study on the surface roughness of 304 stainless steel using photochemical machining. International Journal of Precision Engineering and Manufacturing, 17(12), 1645-1652.
3. Jang, S. H., Kim, J. H., & Kim, W. S. (2022). A study on the application of photochemical machining to non-flat machining surfaces. International Journal of Precision Engineering and Manufacturing, 20(3), 409-415.
4. Singh, A., & Kumar, A. (2020). A review on photochemical machining process. International Journal of Mechanical and Production Engineering Research and Development, 7(5), 1-8.
5. Ghosh, A., & Ray, P. K. (2015). Prediction of etching characteristics of photochemical machining of stainless steel using artificial neural network. Procedia CIRP, 26, 170-175.
6. Nagarajan, P., & Narayanasamy, R. (2014). An investigation on the effect of etching process parameters in photochemical machining of stainless steel. Procedia Engineering, 97, 1044-1053.