Current Density Distribution and Material Removal Behavior on the Graphite/Iron-matrix Interface in Grey Cast Iron Under Pulse Electrochemical Machining Conditions

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Abstract

Pulse Electrochemical Machining (PECM) is an unconventional procedure combining pulsed current and pulsed cathode feed rate (Figure 1), being very suitable for high precision production in series manufacturing. The main advantage compared to conventional electrochemical processes is that the current pulse is only triggered when the efficiency is at its maximum, e.g. at the bottom dead center. This allows reaching smaller gaps (between 10 and 30 micrometers) than by other electrochemical processes, which means more accuracy [1]. Besides, during the pulse off-time the electrolyte in the interelectrode gap is refreshed by the removal product free electrolyte, which guarantees an optimal electrochemical removal condition for each new current pulse. In order to predict the machined surface roughness and topography, COMSOL Multiphysics 4.2a was used in this study to simulate the electric current density distribution, and thus the dissolution behavior of gray cast iron, under pulse electrochemical machining conditions on a metallography-scale. Therefore, the graphite distribution in the iron matrix, and thus the material characteristics, were directly imported from experimental scanning electron microscopy investigations via the image-to-material function in the numerical model geometry. Since graphite cannot dissolve because it is electrochemically inert and as iron is more electrically conductive as carbon, boundary effects appear on the iron/graphite interface. The electrical field is modified and hence the local current density as well [2], leading to inhomogeneous metal removal and thus poor surface integrity. The simulation can help engineers to predict and, if possible, to handle these phenomena. The first simulation and experimental results show a good accordance. Figure 3 represents the current density distribution on a simulated lamellar gray cast iron sample. At the graphite/iron boundary a local current density amplification takes place, enhancing the material removal. This complies with the experimental observations obtained with scanning electron microscopy (Figure 4). After pulse electrochemical machining of the samples, craters appear around the graphite lamella, implying that more material was removed at the graphite/iron interface. In conclusion, this study and the developed model will help predicting the material removal behavior of cast iron and choosing the optimal process conditions to obtain the desired surface quality.

Reference

1. K.P. Rajurkar, D. Zhu et al., New development in electrochemical machining, Ann. CIRP, 48(2):567-579, 1999.
2. O. Weber, H. Natter et al., Surface quality and process behavior during Precise Electrochemical Machining of cast iron, Proceedings of the 7th International Symposium on Electrochemical Machining Technology, 1:41-46, 2011.

Figures used in the abstract

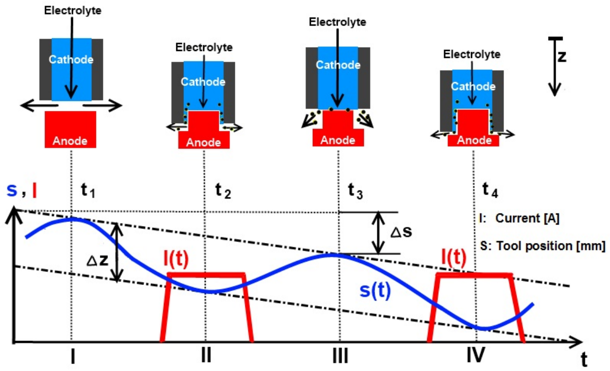

Figure 1: Principle of pulse electrochemical machining.

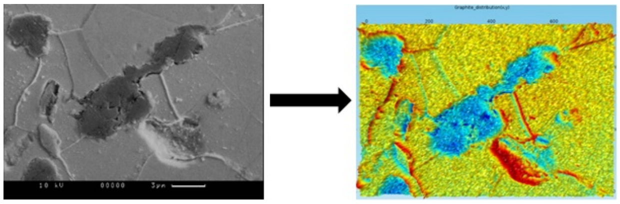

Figure 2: Graphite distribution import in COMSOL.

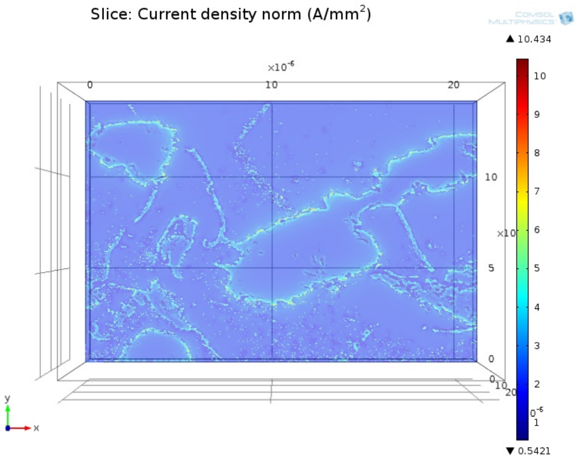

Figure 3: Simulated current density distribution.

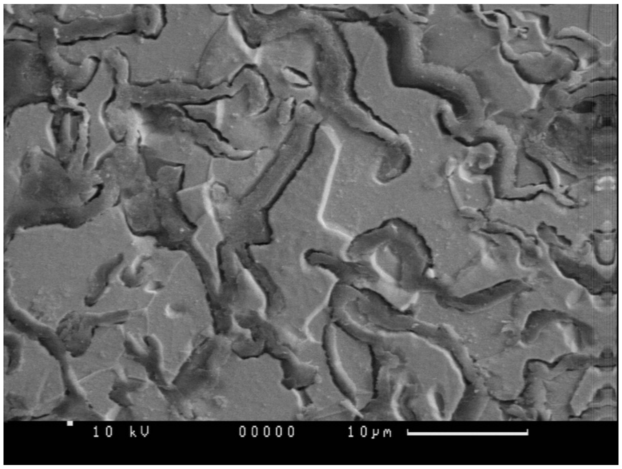

Figure 4: Machined lamellar gray cast iron sample.