The Effect of Electrolyte Flow Slots in Tooling Electrodes on Workpiece Surface Finish in Electrochemical Machining

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Abstract

Electrochemical machining (ECM) is a non-conventional machining process that uses electrolysis to precisely remove material at high rates. ECM has many advantages over conventional machining: no tool wear, no induced mechanical or thermal stresses, high removal rates virtually independent of material hardness or strength, and excellent surface finishes. However, challenges can arise during the design of the tooling electrode when considering the influence of electrolyte flow slots on the final shape of the anode workpiece. Through-tool flow slots can often leave pips, or ridges, of excessive size on the anode because of the increased electrical resistance under the slot areas. A model to predict the final machining surface in the presence of gaps--electrolyte flow slots in the tooling electrode--is created using COMSOL Multiphysics® finite element software. The electric currents and deformed geometry modules were used to model the electrolyte in-between the two electrodes: a potential was applied to the anode and the cathode was grounded. The electrolyte used was 4M NaCl, and conductivity values were taken as 0.75 S/m. Tool feed rate, electrode gap size, and material electrochemical constants were entered into the model, and workpiece recession rate was modeled as a function of the resulting normal current density in accordance with Faraday's law of electrolysis. These results were compared to aluminum samples electrochemically machined with various electrolyte flow slot configurations. A profilometer was used to measure the ridge height on the samples and overall surface roughness. Good agreement was shown between the modeled and experimental ridge heights. Through the use of this model, it is possible to predict and more accurately design electrolyte flow slots to meet final part tolerances and requirements.

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Figures used in the abstract

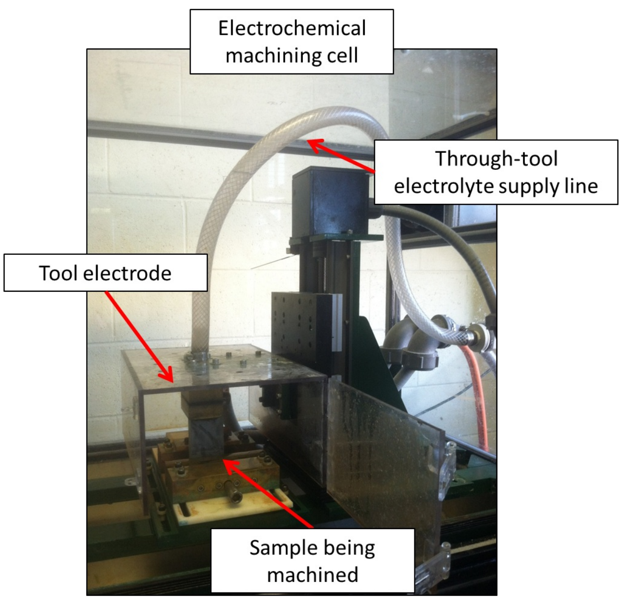

Figure 1: Electrochemical machining setup used during experimentation.

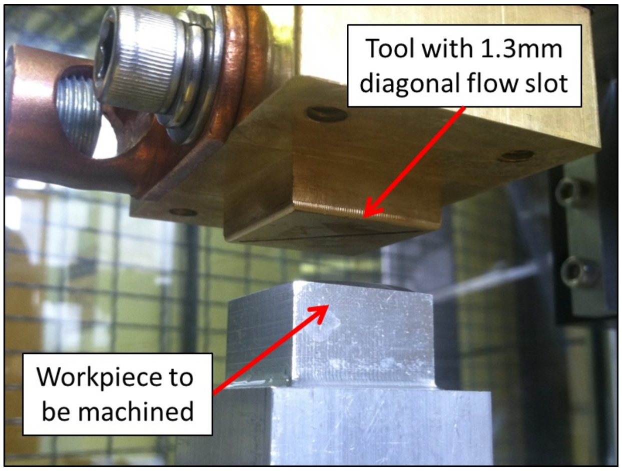

Figure 2: Sample electrode design with diagonal electrolyte flow slot.

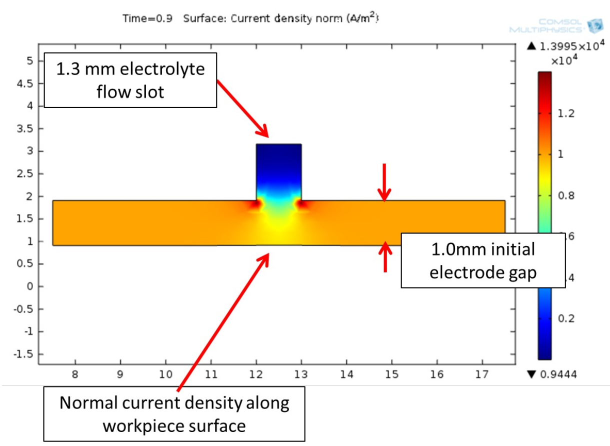

Figure 3: Inital COMSOL model (time = 0) showing the normal current density distribution. The cathode (tool) is top, the anode (workpiece) is bottom, and the electrolyte is center (modeled in COMSOL).

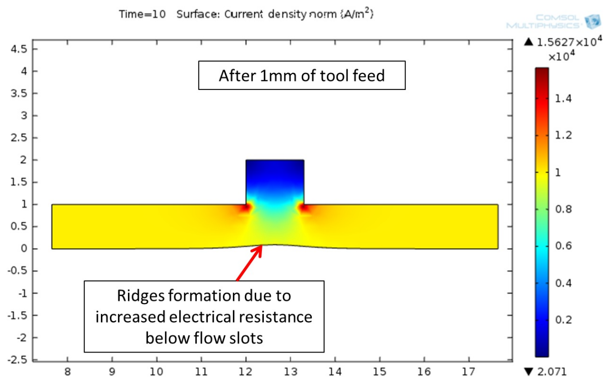

Figure 4: Machined workpiece surface at time = t, ridges can be seen in area underneath electrolyte flow slot.