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Finite element analysis for shape prediction of micro-dimples produced through ECMM

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Two solid surfaces interacting with each other result in a loss of material called wear which is mainly caused due to friction, abrasion, erosion and corrosion. Research is going on in this field to reduce wear and increase efficiency of the system. One solution is to micro-texture the interacting surfaces which effectively reduces the interactive area between them. In this regard, the paper presents mathematical analysis of machining micro-dimples using Electro-Chemical Micro Machining (ECMM). A finite element simulation [2, 4] for the same has been carried out to study the effect of different parameters and to capture the profile of micro-dimple. Figure 1 shows the schematic for the setup.

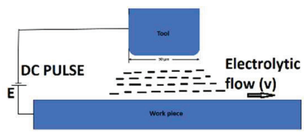

Figure 1: ECMM setup schematic

ECMM is a complex process with many parameters playing significant role in the machining process. Mathematical models [1, 3] have been developed to get a clear understanding of their effects. Complexity arises as some amount of anode (work-piece) dissolute into the electrolyte, correspondingly some amount of hydrogen gas is also evolved at the cathode (tool) by which the properties of electrolyte change. An effort has been made to incorporate the effect of these extra constituents in the electrolyte including their transport along the anode surface.

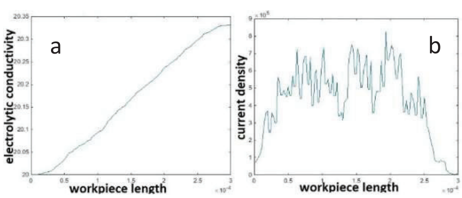

Figure 2: (a) Electrolytic conductivity along the anode surface (b) Current density variation along anode surface

A rectangular bit tool as shown in Figure 1 with some corner radius and Stainless Steel work-piece are considered. Temperature along the anode surface is calculated using Joule heating neglecting other losses. A transport equation is formulated at the anode surface to evaluate the amount of sludge dissolved at anode and amount of hydrogen gas evolved at cathode at any instant. This information along with temperature variation is used to evaluate the electrolytic conductivity.

As voltage is applied between anode and cathode, the electric field lines are governed by Laplace's equation. Over potentials at the electrodes are neglected. After solving Laplace's equation, potential at each node of the triangular element is obtained. From the above information, potential gradient established in the electrolyte is used to calculate current density which in turn gives the material removal rate at each node on anode surface. Figure 3(a) shows mesh in electrolyte and tool and workpiece. Figure 3(b) shows variation in amount of sludge and hydrogen.

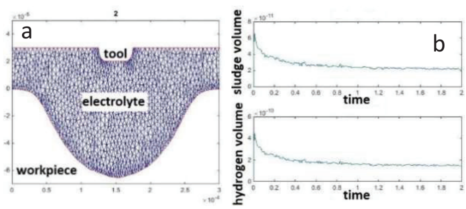

Figure 3: (a) Micro-dimple for zero feed rate (b) Sludge and hydrogen variation with time

From the simulated results, it is observed that the flow rate affects the anode dissolution rate. The higher the flow rate, the faster the sludge and hydrogen are removed and hence, less is the effect of them on the dissolution rate. Also, the effect of temperature on electrolyte conductivity dominates at low flow rate but its effect diminishes with increasing flow rate. The paper proposes future scope for analysing the effect of feed rate at equilibrium inter-electrode-gap and the effect of various other parameters like voltage, electrolytic conductivity. Multi-tool simulation for anode profile will be carried out, followed by experimental investigation and validation of simulated results.

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