SCHOOL OF ENGINEERING & COMPUTING

Automated Electrochemical Deburring System for Micro-Orifices™ Using Precision Actuation

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BACKGROUND

- During the drilling of small orifices, tiny metal burrs can form at the edges, especially in stainless steel components.
- These burrs may block fluid flow, interfere with sealing, or reduce overall part reliability.
- Aerospace, medical device, and pneumatic component manufacturers often require flawless internal surfaces to ensure performance and safety.
- Traditional deburring techniques such as manual grinding, thermal deburring, chemical etching, and laser ablation have limitations including:
  - Inconsistency and operator error (manual grinding)
  - Risk of heat damage (thermal, laser)
  - Difficulty controlling removal in precise areas (chemical)
  - High cost and environmental concerns
- Electrochemical Machining (ECM) is a non-contact method that removes burrs without mechanical stress or heat.

OBJECTIVES

- Develop an automated system to remove burrs from micro-orifices ranging from 1 to 125 thousandths of an inch.
- Achieve consistent, sub-micron accuracy in burr removal without damaging surrounding material.
- Improve upon traditional manual or mechanical methods by offering an automated, scalable, and repeatable solution.
- Provide a safe, operator-friendly, and cost-effective alternative suitable for industries with precision manufacturing needs.

METHODOLOGY

- A conductive needle is insulated along its shaft, exposing only the tip to target burrs inside the orifice.
- An electrical potential (15V) is applied across the needle and workpiece in a 5% NaCl electrolyte bath, causing controlled material dissolution.
- Needle depth is calibrated using measurements, not visual feedback. A linear actuator positions the needle based on predetermined travel distances for each orifice size.
- Testing was conducted on stainless steel parts with machined orifices, first with visible burrs, then examined under magnification post-ECM.
- Variables such as voltage, electrolyte concentration, and time were controlled. Current configuration: 15V, 10s, 5% NaCl.

(a) (b)

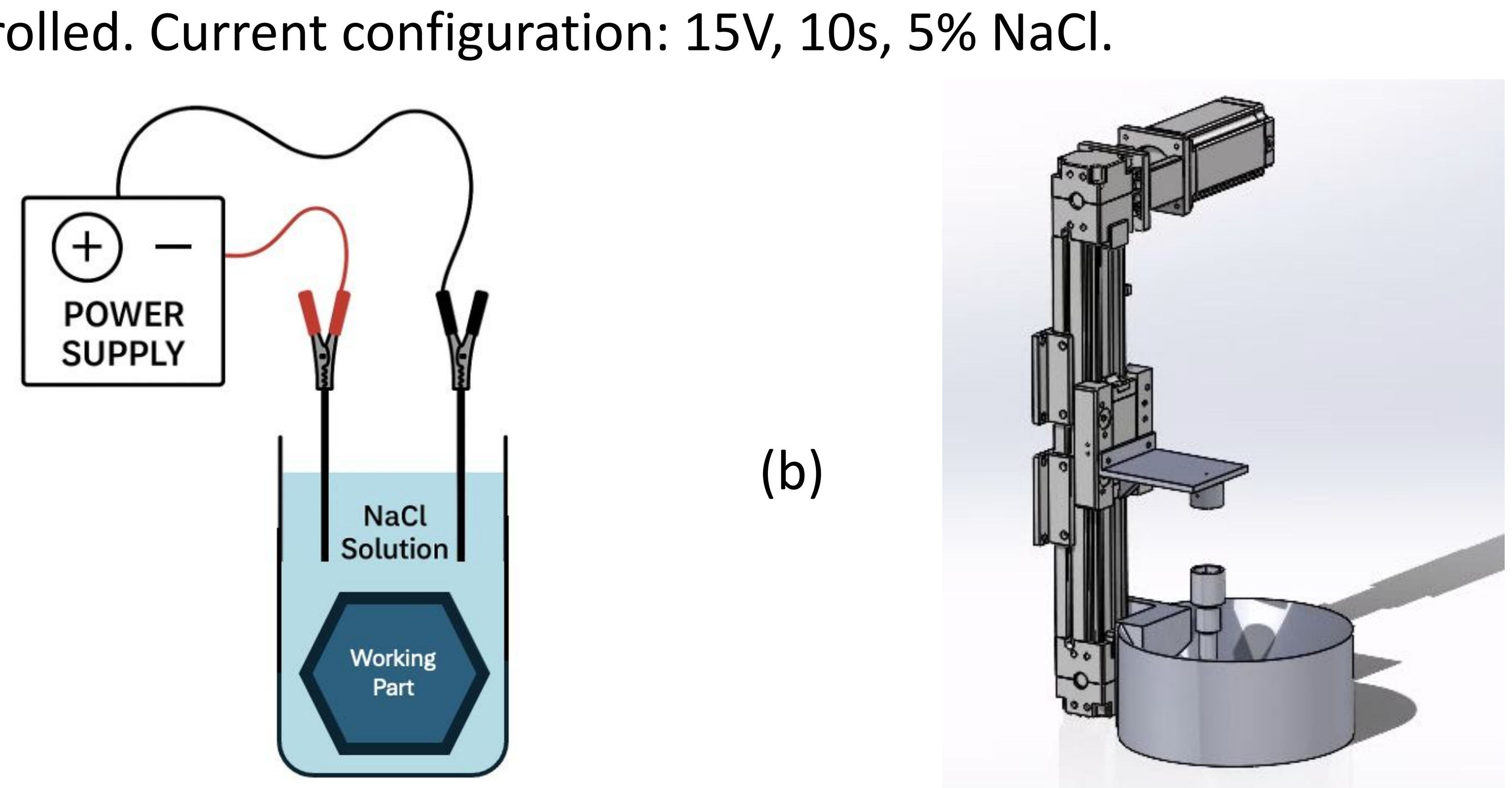

Fig. 1. (a) Basic Diagram of ECM Procedure using NaCl solution and power supply. (b) SolidWorks Apparatus with linear actuator, tool, and workpiece

Material Removal Rate

The main equation we used to determine the material removal rate, *MRR* which is in units of g/s:

$$MRR = \frac{V}{t} = \frac{CEA}{gr}$$

where *V* is the volume of metal removed in units of mm^3, *t* is the time of Electrochemical machining in units of seconds, *C* is the Electrochemical Constant which has units of mm^3/Amp-s, *E* is the voltage being supplied to the part in units of Volts, *A* is the surface area of tool which has units of mm^2, *g* is the gap between the tool and the workpiece in mm, and *r* is the resistivity of the electrolyte which has units of Ohm-mm.

RESULTS

(a) (b) (c)

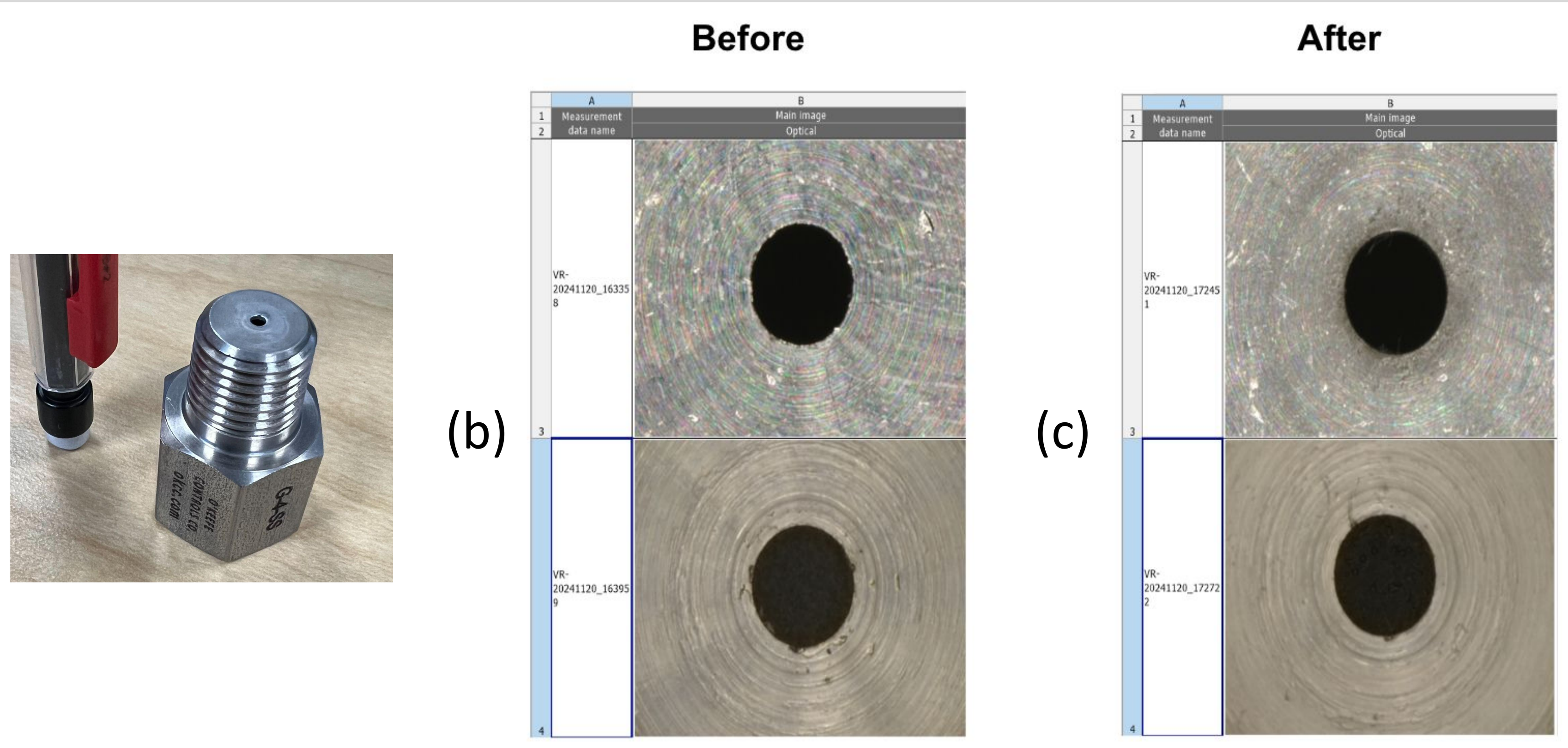

Fig. 2. (a) Scaling of micro orifice compared to workpiece (b) Workpiece orifice under Keyence microscope before machining (c) Workpiece orifice under Keyence microscope after machining

DISCUSSION

We initially tested on the workpieces with varying NaCl concentrations of 5%, 7.5%, and 10%. However, due to the high levels of overmachining the micro orifice, we decided to stick with 5% as it yielded the best results under the Keyence microscope. Utilizing the autonomous capability of our apparatus set up, the operator only needs to complete simple tasks such as workpiece placement, adding NaCl solution, and start command with computer. The Arduino IDE provides communication between the linear actuator which regulates the gap between the tool and the workpiece which eliminates sources of error. The 3D printed workpiece holder ensures proper centering between the needle and workpiece while also provides scalability to different geometries in the future.

CONCLUSIONS

- The ECM system successfully removed burrs from micro-orifices with high precision, achieving sub-micron accuracy.
- 5% NaCl electrolyte concentration, 15V voltage, and controlled needle positioning provided consistent material removal and surface quality.
- Arduino-controlled linear actuation allowed for a repeatable, automated deburring process, improving efficiency.
- 3D-printed workpiece holder offers flexibility for different geometries for further refinements and broader industrial applications.

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