3-axis CNC Electrochemical Machine

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Abstract

In engineering and manufacturing, blending traditional methods with modern technology can yield remarkable outcomes. Our design, a 3-axis CNC Electrochemical Machining (ECM) tool, showcases this synergy, merging precision 3-axis CNC motion control with ECM's specialty in machining hard metals like titanium and hardened steels. The testing protocol involved finding optimal feed rate, amperage, voltage, and fluid flow method. They were then implemented in the rest of the design.

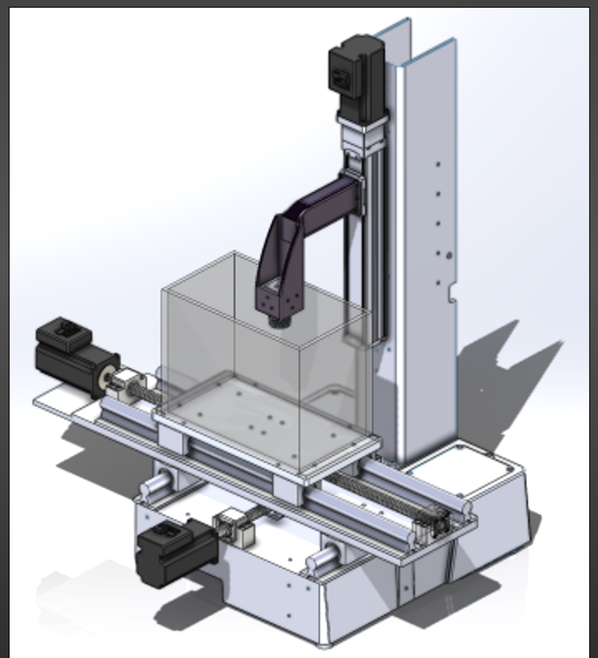

Figure 1: CAD model of final assembly of CNC ECM machine design.

Table 1: Critical metric table, optimal values and units, and achieved values and units.

Metrics	Marginal	Ideal
Tolerance	±0.5 mm	±0.1 mm
Repeatability	90%	95%
Input Power	120V/20A	120V/15A
Dry Weight	350 lbs.	200 lbs.
Machine footprint	1 - 2 m^2	1 m^2
# feeds and speeds	2	10

Problem

CNC can shape parts in any way, and ECM can work with any conductive material. But ECM isn't as flexible as CNC. How do you mix CNC's flexibility with ECM's strength?

Methods

We aimed to develop a machine tool that encapsulates the robustness of a 3-axis CNC milling machine with the distinct advantages of ECM. We broke it down into logical sections that each had major decisions to be made on the build. The sections are: mechanical structure and frame, linear motion assemblies, axis motion drivers, ECM integration, control and interface systems, and electrical design and safety interlocks. The testing space is shown in figure 4.

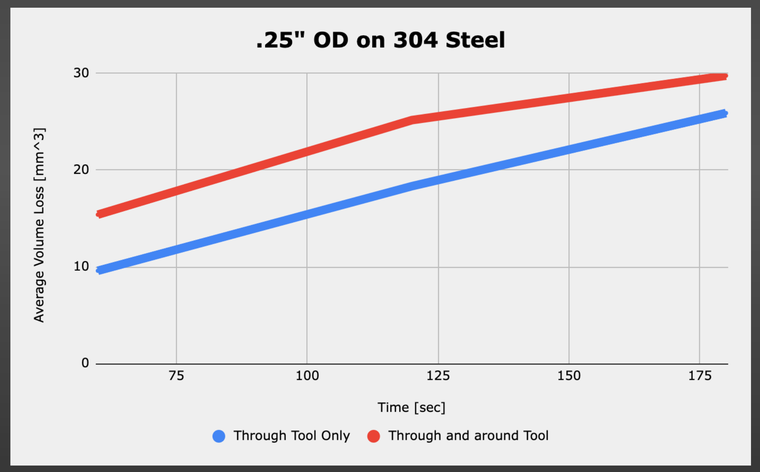

Figure 2: Average volume loss of machining on 304 steel using 0.25” tool.

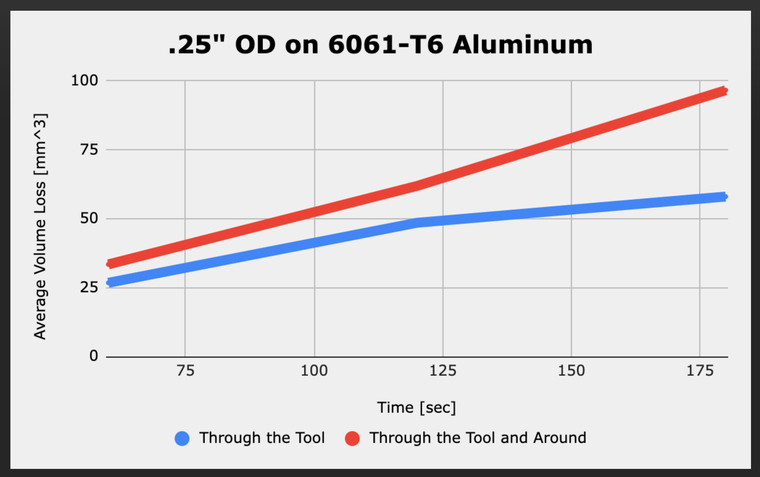

Figure 3: Average volume loss of machining on 6061-T6 aluminum using 0.25” tool.

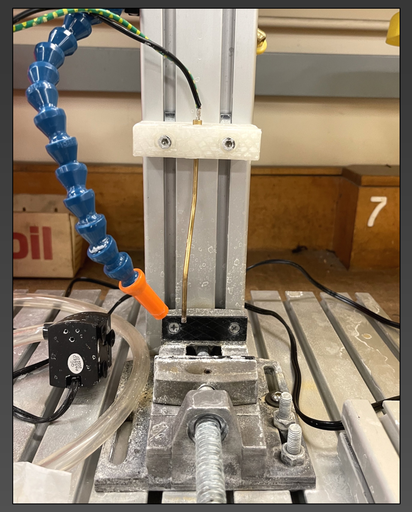

Figure 4: Image of previous testing workspace for data gathering.

Results

Our cutting data shows that for cutting the most material in the shortest time having fluid flowing through the tool and outside the tool is the best. This is in part due to there being more fluid for the amperage and voltage to move through. Figures 2 and 3 are the two types of materials that yielded the best results. Additionally, We found that down-stream machining is more effective than submerged machining because of the accuracy that this cutting method provides. However, the biggest hurdle that we encountered was having the fluid be contained in a separate location and using tubing to direct the fluid from the tank to the tool and back.

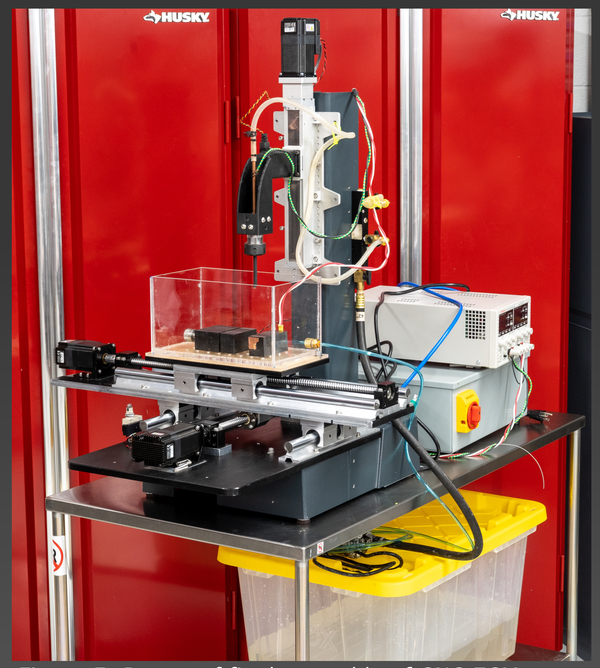

Figure 5: Image of final assembly of CNC ECM machine tool. Portrayed in this assembly are the mechanical components, full frame assembly, electrical power supply, and chosen fluid circulation system.

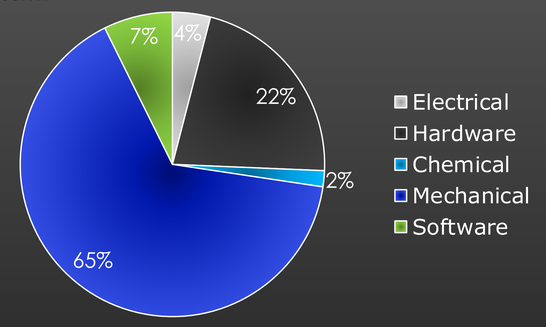

Figure 6: Budget distribution of project. Money spent totaled to $5,187, which fell under projected dollar amount.

Conclusion

The design and product are as aesthetic, effective, and precise as projected. Additionally, the assembly and components fell under budget as predicted. The amount of testing done allowed us to better establish feed, amperage, and voltage ratings for the product with the best finish, accuracy, while done in a timely manner. The primary participant in the completion of this product was also the sponsor of the project, whom we thank for cooperation and financial support.