METHOD OF MATERIAL REMOVAL BY MEANS OF ELECTROCHEMICAL TURNING

Applying ECM Theory to Conventional Machining Techniques

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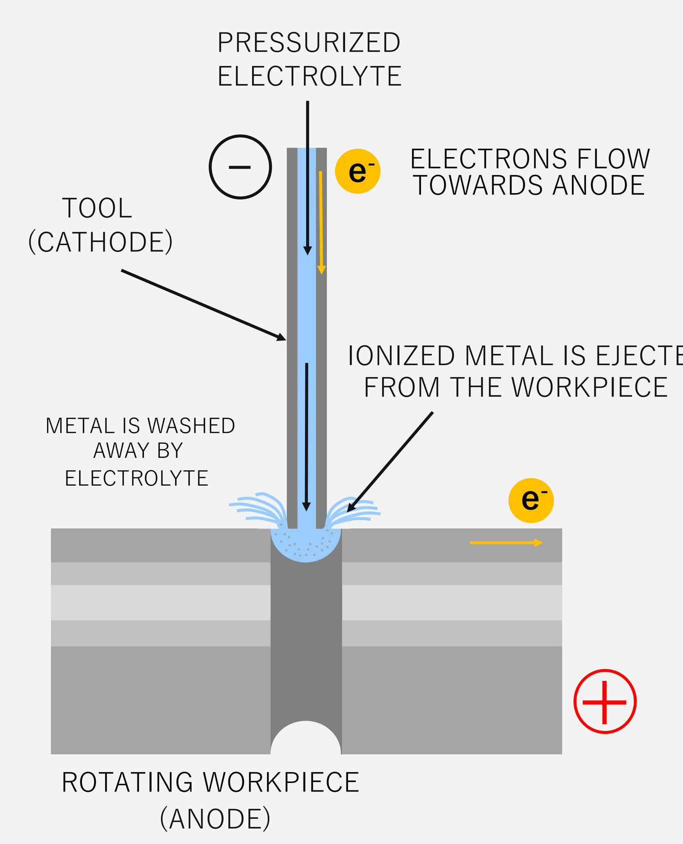
1 ABSTRACT

High strength materials designed to operate in extreme conditions are difficult to cut for the same reasons that make them excellent for demanding applications. These materials are called "superalloys", and are commonly found in aerospace applications. Conventional cutting methods such as milling and turning can expend thousands of dollars' worth of tools on a single part. Electrochemical Machining (ECM) is a non-contact method of machining that uses controlled anodic dissolution to remove material from a conductive workpiece at the atomic level. Material is removed under a high pressure electrolyte (1-20 atmospheres). ECM operations experience no tool wear, and material hardness has no effect on the ECM process. This makes ECM an ideal method for machining exotic materials. Typical ECM operations require in-depth design, tailoring a unique tool (cathode) to each part. As many as 20 iterations can be necessary to create a working cathode for production.

This project serves as a test bed for developing new ECM methods such as the use of non-unique tooling, and for experimentation with different electrolytes. The objective of this project is to make a machine that can cut metals via electrolytic dissolution.

2 THE ECM PROCESS



TYPICAL ECM OPERATING PARAMETERS

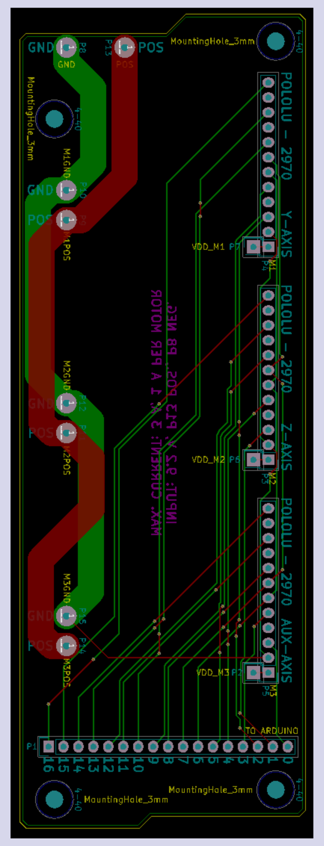
- Electrolyte pressure: between 1 and 20 Atmospheres
- Electrolyte conductivity: 70-80 mS
- Voltage: rarely exceeds 15 V
- Current: 10-400 A, often higher
- Electrolyte Composition: Sodium Nitrate, Sodium Chloride, Sodium Sulfate - other formulas often used

3 SOFTWARE AND ELECTRONICS

- Existing CNC control systems do not support the abstract nature of ECM
- A computer control system was designed and built for this project to allow for customized control settings - software and hardware were developed and implemented within 3 months
- A new G-code dialect was specially made, additional G-codes can be readily added
- Circuit boards were designed and manufactured to carry motor drivers
- Software supports both metric and imperial units

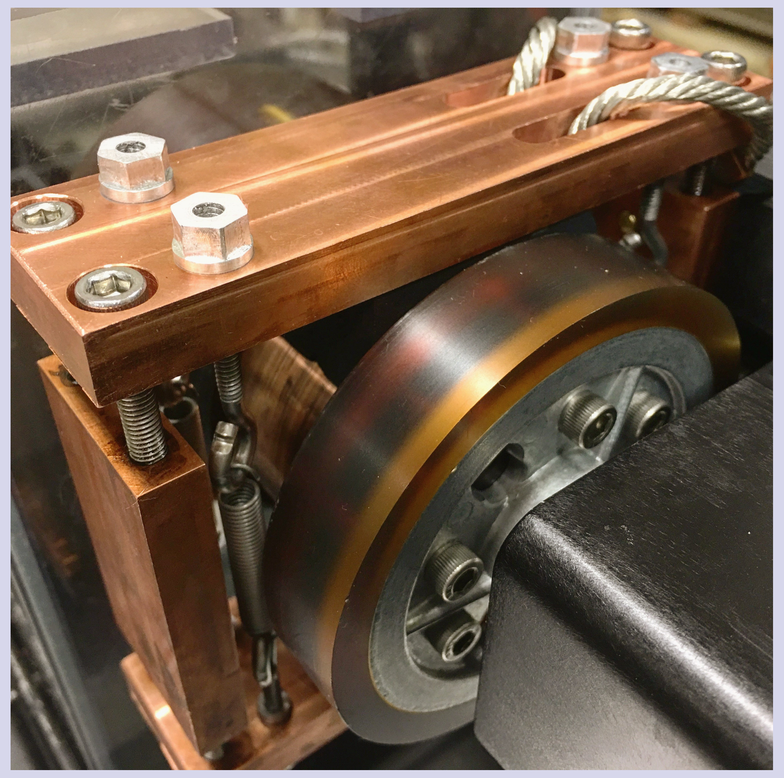
Positioning With Bresenham's Algorithm

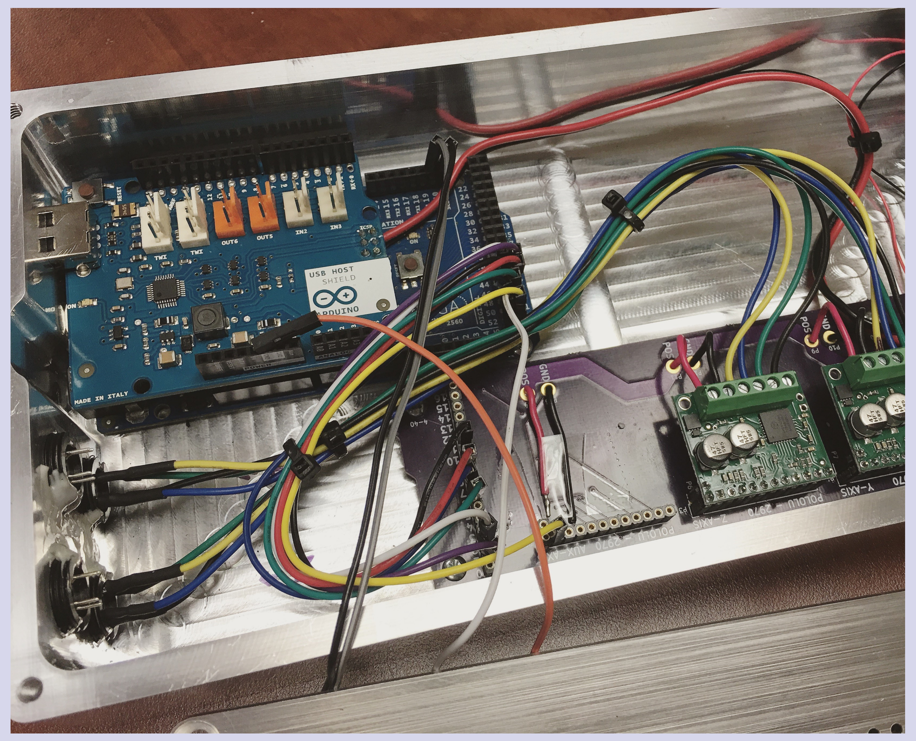
```
//Bresenham's algorithm allows one computer to control several motors simultaneously
if(dy>dz) //Defining which octant to operate Bresenham's algorithm in
  {
    err = dy/2; //Scenario where the Y direction is governing Bresenham's algorithm
    for(i=0; i<dy; ++i)
    {
      stepper1.setDirection(diry); //Tells the Y-axis motor which way to step
      step1(); //Tells motor 1 (Y axis) to take a step
      err += dz; //Difference between desired and actual position after a step
      if(err >= dy) //Steps the other axis if necessary to keep tool travel linear
      {
        err -= dy; //Actual position is now closer to the desired position
        stepper2.setDirection(dirz); //Tells the Z-axis motor which way to step
        step2(); //Tells motor 2 (Z axis) to take a step
      }
      delayMicrosecondsLong(step_delay); //The delay between steps sets the feed rate
    }
  }
```



4 MACHINE DESIGN

- Providing electricity to a rotating part was accomplished with graphite brushes under spring tension
- Polyetherimide plastic was used to electrically isolate charged components
- Machine spindle is made from multiple metals for emphasis on corrosion resistance and conductivity where needed
- Machine positioning accurate to .001" with consistent .003" backlash





- An Arduino Mega microcontroller is used to receive communications from a user's PC
- Positioning is accomplished with AMIS-30543 stepper drivers and bipolar stepper motors
- LCD screen on lathe computer alerts operators to machine status
- Serial Peripheral Interface bus is used for communications between electronic components

5 THEORY AND OPERATION

ECM Material Removal Rate

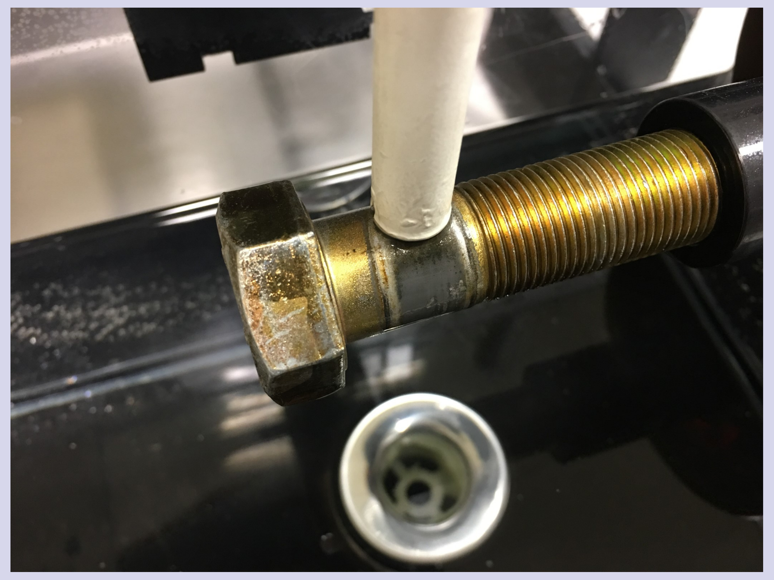
$$MRR = \frac{IA}{F\rho}$$

Where ***MRR*** represents the material removal rate, ***I*** represents supplied current, ***A*** is a material constant calculated based on material properties and experimentation, ***F*** is the Faraday constant, and ρ is material density. Machining efficiency is a component of the material constant ***A***. Efficiencies above 100% are possible when entire grains of metal are removed instead of single atoms. Typical efficiencies are under 100% - electrical energy not used for machining is dissipated as heat, or through hydrogen evolution at the part.

The image to the right shows a grade 8 bolt being cut inside the machining enclosure during early machining trials. Careful positioning of the cathode and precise control over all process parameters is necessary to provide good results.

6 RESULTS

- The machine developed is capable of removing metal atoms from a workpiece without physical contact, through electrolytic dissolution
- This was done at a fraction of an industrial machine's price
- This machine has proven the viability of graphite brushes for the transfer of extreme current to a moving part



7 REFERENCES AND ACKNOWLEDGEMENTS

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