MEED For Speed

Metallic Erosion Evaluation Device (MEED)

DEPARTMENT OF MECHANICAL ENGINEERING

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Motivation, Goal, Impact

- **Need:** NSWC Carderock Division requires an in-house metallic erosion evaluation device.
- **Purpose:** Support metal alloy selection for LCAC fan blades, which experience rapid erosion from sand particle impacts during shoreline operations.
- **Solution:** Adapt a commercial sandblaster for rapid, cost-effective preliminary erosion testing on metal samples.
- **Benefit:** Quickly narrow down candidate alloys before proceeding to time-consuming and expensive external testing.

Requirements

- Adapt an ECONOLINE Mini Blast Cabinet
- Ensure repeatable results for each alloy
- Maintain precise impingement distance to samples (10 mm)
- 90° sandblasting impingement angle
- Use compressed air with 80 grit Al_2O_3 media
- Tests multiple samples per round
- Accommodates samples from 0.25" × 0.25" up to 1" × 1"

Final Design

Blaster Subsystem

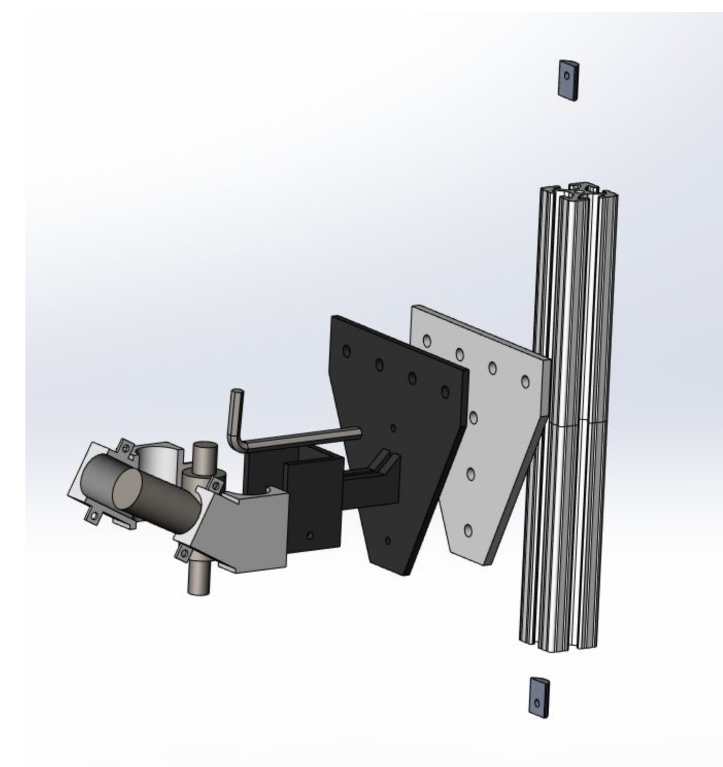
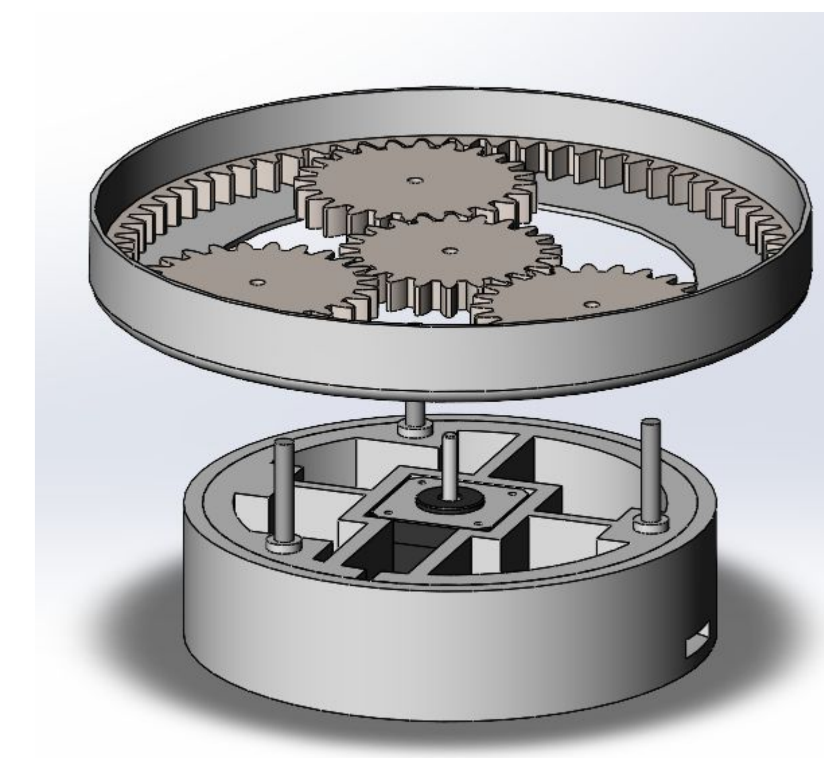
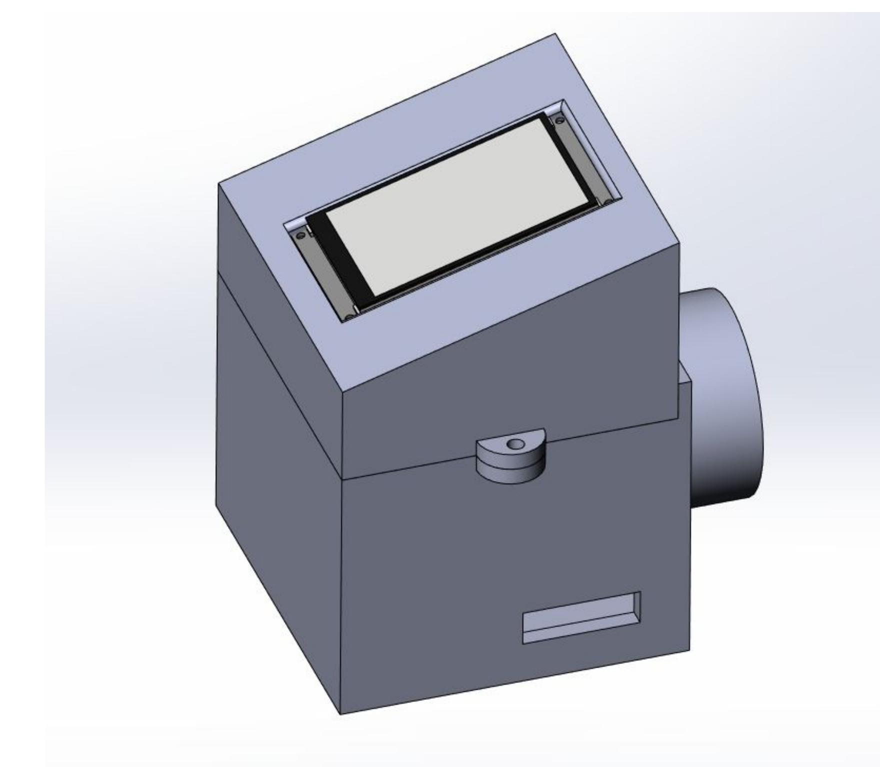


Plate Actuation Subsystem



UI Subsystem



Design Calculations & Decisions

Solenoid Valve Decisions:

- Force to press button, decision to switch
- Power requirements, current draw

Environmental Impact:

- Initial design had vices to hold samples
- One factor in decision to use putty was the environmental impact study we did (find the chart for this)

Blasting Recoil Calculations:

- Around 15 lbs of force will be hitting the bottom plate
- 15 lbs of force acting upward on gun nozzle
  - This force will be fighting against gravity - not a concern

Lazy Susan Gear Ratios:

- 4.18:1 planetary gear ratio for actuation
- Maximum torque output increased from 42 N-cm to 175.64 N-cm

Planetary Gearset Equation:

$$\text{Gear Ratio: } 1+\frac{Z_{Ring}}{Z_{Sun}},\ Z_{Ring}=70,\ Z_{Sun}=22$$

$$\text{Gear Ratio} = 1+\frac{70}{22}=4.182$$

Compressed Air Recoil Calculations

$$\text{Bernoulli Equation: } P_1+\frac{1}{2}\rho V_1^2+\rho g h_1=P_2+\frac{1}{2}\rho V_2^2+\rho g h_2$$

$$P_{air}=104\ PSI\approx 717055\ Pa$$

$$\dot{V}_{air}=6CFM=\frac{6ft^3}{min}\cdot\left(\frac{0.3048\ m}{1\ ft}\right)^3=0.1699\ \frac{m^3}{min}\cdot\frac{1\ min}{60\ sec}=0.00283\ \frac{m^3}{s}$$

$$D_{nozzle}=0.25\ inch\approx 0.00636\ m$$

$$D_{air\ tube}=0.5\ inch\approx 0.0127\ m$$

$$\rho_{air}=1.293\ \frac{kg}{m^3}$$

$$\dot{V}=V_1A,\ V_1=\frac{\dot{V}}{A}=\frac{0.00283\ \frac{m^3}{s}}{\frac{\pi}{4}(0.0127)^2}=22.34\frac{m}{s}$$

$$\dot{m}_{air,in}=\dot{m}_{air,out}\quad \rho A_1V_1=\rho A_2V_2$$

$$V_2=\frac{A_1V_1}{A_2}=89.361\ \frac{m}{s}$$

$$717055\ Pa+\frac{1}{2}\left(1.293\frac{kg}{m^3}\right)\left(22.34\frac{m}{s}\right)^2=P_2+\frac{1}{2}\left(1.293\frac{kg}{m^3}\right)\left(89.361\frac{m}{s}\right)^2$$

$$P_2=712244\ Pa$$

$$\text{Momentum Equation: } \int_{cs}\rho V(V\cdot n)dA=\sum F_{CV}=-\int_{cs}\rho n d+\int_{cv}\rho g dV+R$$

$$\rho V_1A_1+\rho V_2A_2=-[-P_1A_1+P_2A_2]+R$$

$$R=-\rho V_1^2A_1+\rho V_2^2A_2+P_2A_2-P_1A_1=67.96\ N\approx 15.28\ lb\ force$$

Prototype & Test Results

Blaster Subsystem:

- Solenoid switches on and off
- Allows sufficient airflow, meaning blaster still erodes material

Plate Actuation Subsystem:

- Lazy Susan Design, allowing for 0-10 samples of various sizes and heights to be tested
- Powered by a Servo motor that integrates into a planetary gear system
- Repeatable, test results
  - Top plate sample alignment marks
  - Consistent “radius of impact”
  - “Start” position

User Interface Subsystem:

- 5 main screen inputs
  - # of samples
  - time per sample
  - Start
  - Emergency Stop
  - Reset
- Screen allows users to input desired testing conditions, which integrates into microcontroller
- The code is modular, scalable for future upgrades
- Facilitates a nearly fully automated system