Mechanical Engineering Portfolio

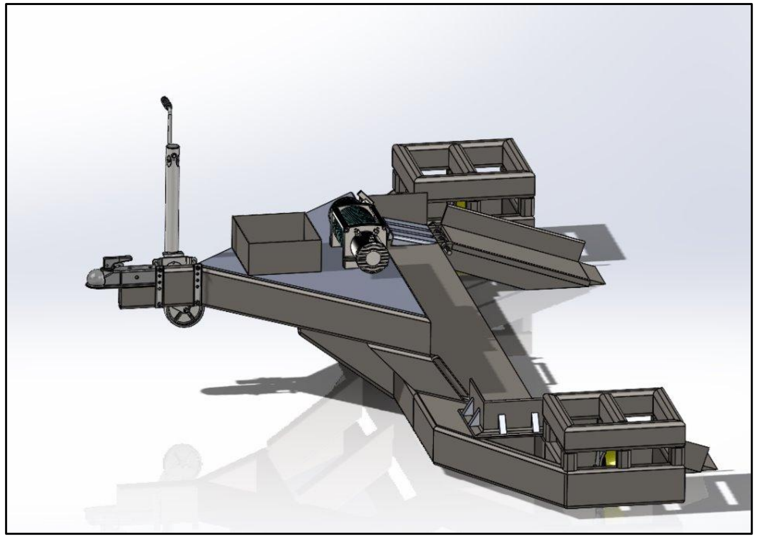
ANNELISE CUNEO

annelisecuneo@gmail.com | (530) 388 – 6830 | LinkedIn.com/in/ann-cuneo

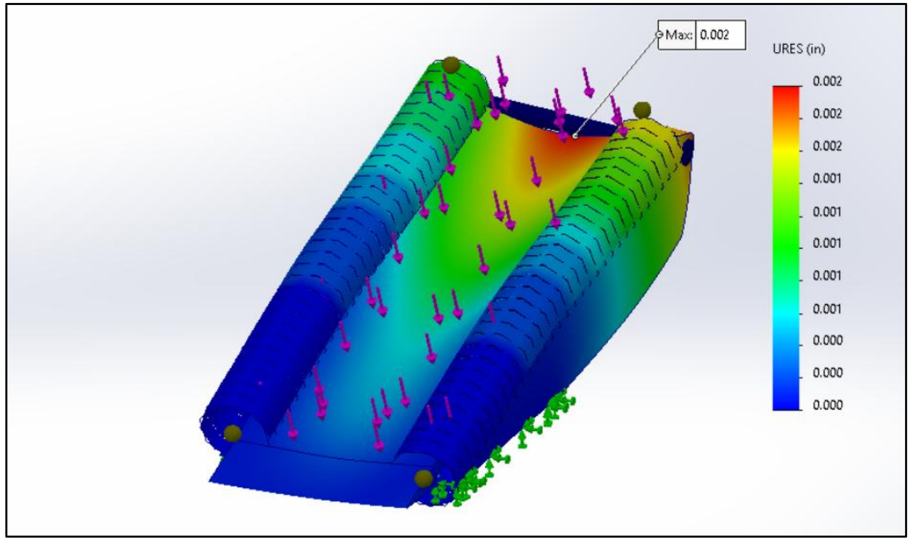
CONTENTS

Capstone Project – Trailer Transport System

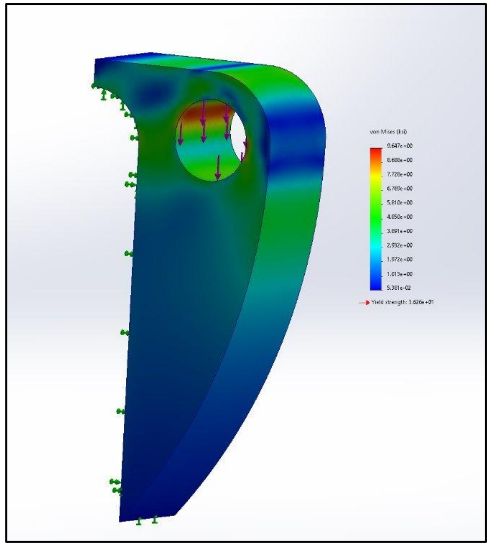
- **Led the project as Chief Engineer**, managing planning, scheduling, and formal design reviews (**PDR/CDR/IDR/FDR**), along with client communication and deliverables. Delegated tasks, reallocated work when critical pieces lagged, and rebuilt weak drafts into **professional, client-approved outputs**, keeping morale and accountability high in a low-motivation team.
- **Engineered a 12×6 ft transport system in SolidWorks to move 5-ton bins with a 90° pivot**, exceeding the 4–6 in. lift requirement by achieving **10 in. of clearance**. Ran load calculations, sized welds per **AWS D1.1** (1/8” fillets on 1/4” A36 steel), and performed **FEA** on ramps, gussets, and hitch points, holding a **factor of safety of 2.5**.



CAD Final Design



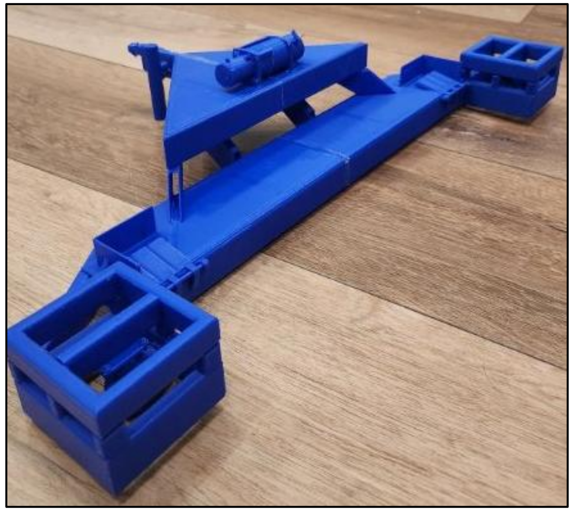
FEA on Ramp



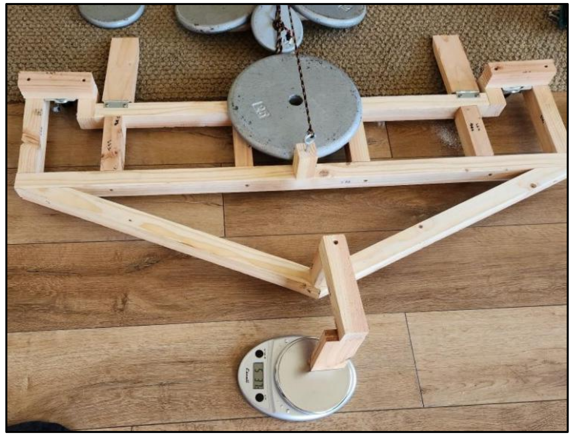
FEA on Support Gusset

Capstone Project – Trailer Transport System

- **Validated design performance through load calculations, scaled prototype testing, and FEA**, confirming weight distribution, tipping stability, ramp clearance, and safety margins.
- **Built and tested scaled prototypes (3D printed and wood)** to confirm functionality and adapt designs under evolving client funding and requirements. Iterated quickly, demonstrating resilience under tight timelines.
- **Produced complete manufacturing documentation**—CAD assemblies, iBOMs, weld diagrams, part sheets, post-weld drilling layouts, and step-by-step assembly instructions—delivering a client-ready design package with measurable improvements: increased safety, reduced operator effort, minimized concrete wear, and a **50% noise reduction.**
    - *Takeaway:* Learned how to **balance stepping in personally** versus **guiding the team** to achieve project goals under challenging conditions.



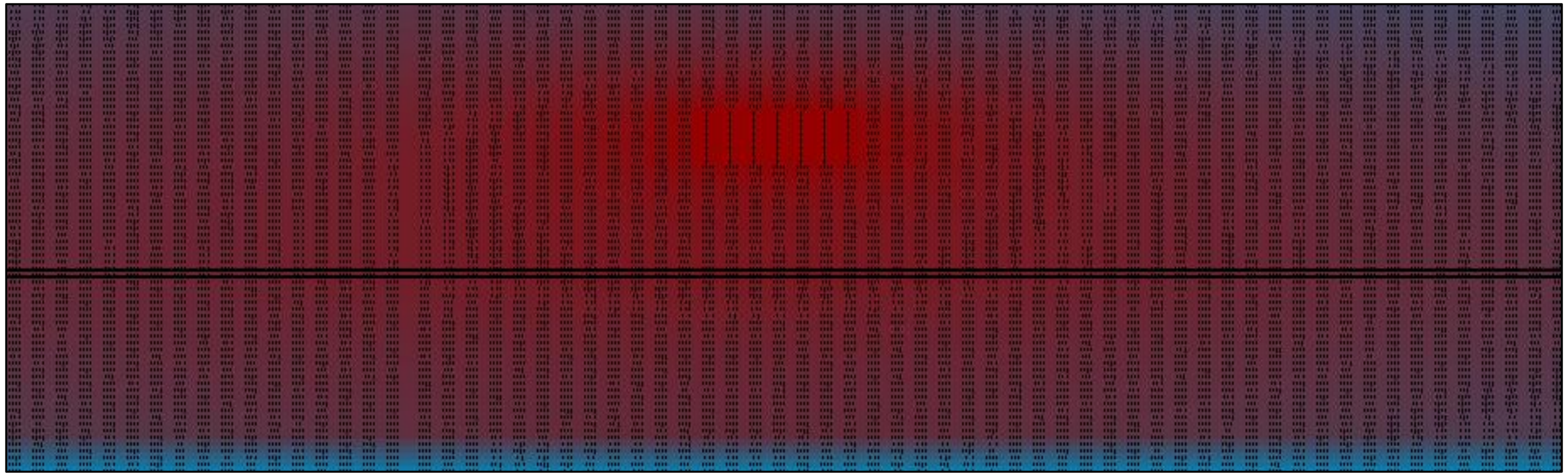
3D Printed Proof of Concept



1:6 Scaled Testing Prototype

Radiant Heating System for Atrium

- **Led thermal analysis and coding**, developing **200+ iterative equations in EES** and calculating **7,200+ data points in Excel** to model temperature distribution and size pumps, heat exchangers, and PEX tubing while optimizing cost, flow, and thermal performance. **Maintained organized calculation files and design records** throughout the project.
- **Performed full thermal and hydraulic calculations**, including heat transfer (**U = 5.641 BTU/hr-ft-°F**), pressure losses via Bernoulli, flow rates, LMTD for heat exchangers, surface and floor temperature profiles, and energy requirements for startup (**18,000 BTU/hr**) and steady state (**11,500 BTU/hr**).



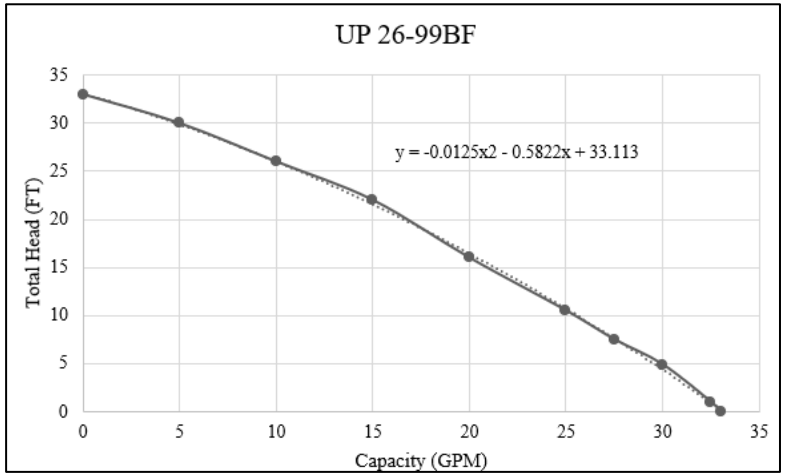
Temperature Distribution of Concrete Section

```
"NTU Method to determine heat exchanger - shell is heat exchange

  UA = 453.5 [BTU/hr-F]
  Q_tube_hx = (23 [l/min])*convert(l/min,ft^3/hr)

//Shell Side - system

  C_shell = m_dot_total*cp_water*convert(BTU/s-F,BTU/hr-F)

//Tube Side - Heat Exchanger

  T_hx_in = 180 [F]
  T_m_hx = 0.5*(T_hx_in + T_hx_out)
  cp_tube=cp(Water,T=T_m_hx,x=0)
  rho_tube=density(Water,T=T_m_hx,x=0)

  Percent_flow = 0.085
//  Percent_flow = 0.05
  m_dot_tube = percent_flow*rho_tube*Q_tube_hx
  v_dot_tube = (m_dot_tube/rho_tube)*convert(ft^3/hr,ft^3/s)

  C_tube = m_dot_tube*cp_tube

  C_min = min(C_tube, C_shell)
  C_max = max(C_tube, C_shell)

  NTU = UA/C_min
  epsilon =HX('shell&tube_1', NTU, C_tube, C_shell, 'epsilon')

  //Heat transfer Rate

  q_load = C_tube*(T_hx_in-T_hx_out)

  epsilon = q_load/(C_min*(T_hx_in-T_m_o))


  R_LMTD = (T_hx_in-T_hx_out)/(T_m_i-T_m_o)
  P_LMTD = (T_m_i-T_m_o)/(T_hx_in-T_m_o)

  F_LMTD=lmtd_cf('shell&tube_1',P_LMTD,R_LMTD)
```

Heat Exchanger Code Calcs

Radiant Heating System for Atrium

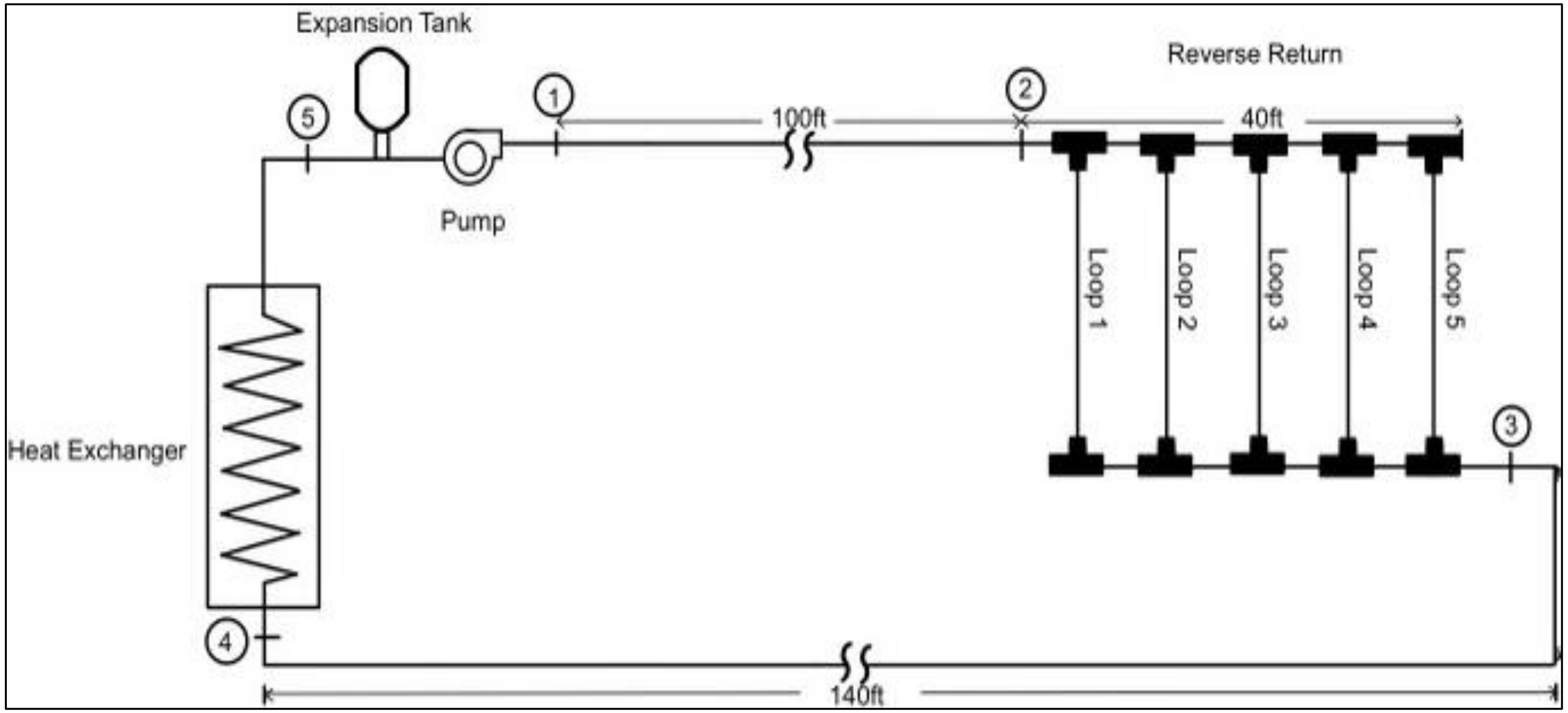
- **Optimized system layout and performance**, selecting **five loops of 1/2–3/4 in. PEX tubing**, a **45,000 BTU/hr heat exchanger**, **2 gal expansion tank**, and pump from simulated pump curves to maintain a **79°F floor and 68°F interior**, exceeding thermal requirements and minimizing total tube length.
- **Executed detailed cost analysis and trade studies**, comparing electrical vs. water-based designs; delivered a system **$16,000 cheaper than the electrical alternative**, remaining under **$29K total** and in the **top 5% of class designs** for cost and warmup efficiency.



Simulated Pump Curve Equation

- **Completed the project from requirements through full submission**, integrating EES, Excel, and MATLAB outputs into a complete design package with insulation selection, component sizing, and step-by-step methodology to translate theory into a practical, energy-efficient solution.
  - *Takeaway:* Maintained rigorous attention to detail, ensured clean, organized code, and proactively stayed on top of deliverables, **enabling early completion ahead of schedule**.

Radiant Heating System for Atrium



Final System Layout

Tube Spacing (in)	Cost ($)	Heat Up < 2.5 hours
10	2092	Pass
11	1899	Pass
12	568	Pass
13	524	Pass
14	487	Fail
15	454	Fail
16	426	Fail
17	401	Fail
18	389	Fail
19	359	Fail

Sample Cost Choice Table

System Dynamics – Linear vs Nonlinear Models

- **Developed and tested MATLAB/Simulink models** of Romi robot behavior, coding multiple scenarios to simulate linear and nonlinear dynamics and plotting motor outputs, chassis position, and angular velocity to evaluate trajectory performance.
- **Created system models**, including **state-space, Jacobian, and block diagram representations**, to visualize control system dynamics and compare linear vs. nonlinear behavior under varying voltage inputs.

```
function [xd, y] = fcn(x, u, p)

% Name and assign State variables to their correct places
i_L     = x(1);
i_R     = x(2);
Omega_L = x(3);
Omega_R = x(4);
v_C     = x(5);
Omega_C = x(6);
psi     = x(7);

% Deal out values of input variables into separate MATLAB variables.
V_L = u(1);
V_R = u(2);

% State Equations
xd = zeros(9,1);
xd(1) = (1/p.L)*(V_L - p.R*i_L - p.k_v*Omega_L);
xd(2) = (1/p.L)*(V_R - p.R*i_R - p.k_v*Omega_R);
xd(3) = (1/p.J_e)*(p.k_t*i_L - p.r*f_tr(p.r*Omega_L + (p.w/2)*Omega_C - v_C) - p.b_m*Omega_L);
xd(4) = (1/p.J_e)*(p.k_t*i_R - p.r*f_tr(p.r*Omega_R - (p.w/2)*Omega_C - v_C) - p.b_m*Omega_R);
xd(5) = (1/p.m_C)*(f_tr(p.r*Omega_L + (p.w/2)*Omega_C - v_C) + f_tr(p.r*Omega_R -(p.w/2)*Omega_C-v_C));
xd(6) = (1/p.J_C)*(p.w/2)*(-f_tr(p.r*Omega_L + (p.w/2)*Omega_C - v_C) + f_tr(p.r*Omega_R -(p.w/2)*Omega_C-v_C));
xd(7) = Omega_C;
xd(8) = v_C*cos(psi);
xd(9) = v_C*sin(psi);
```

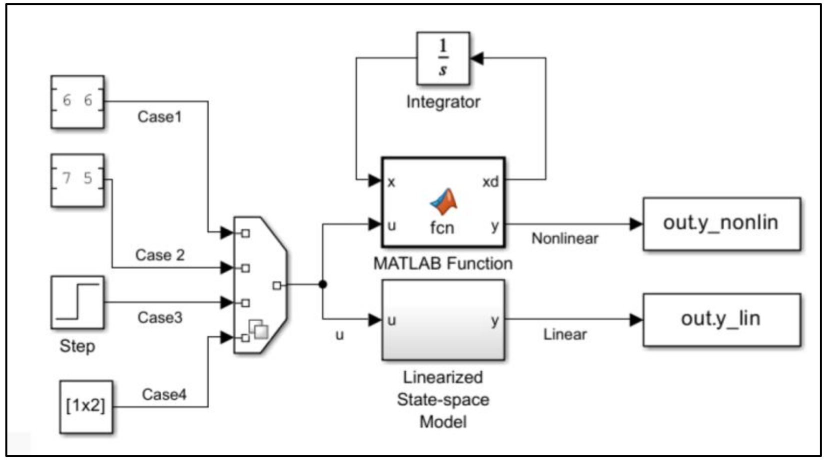
System Equation Snippet

$$
\begin{matrix}
-\frac{R}{L} & 0 & -\frac{k_v}{L} & 0 & 0 & 0 \\
0 & -\frac{R}{L} & 0 & -\frac{k_v}{L} & 0 & 0 \\
\frac{k_t}{J_e} & 0 & -\frac{b_m + \frac{2\,F_{\max}\,r^2 \tan\left(\frac{\pi\,k}{2}\right)}{\hat{v}\,\pi}}{J_e} & 0 & \frac{2\,F_{\max}\,r \tan\left(\frac{\pi\,k}{2}\right)}{J_e\,\hat{v}\,\pi} & -\frac{F_{\max}\,r\,w \tan(\frac{\pi}{2}}{J_e\,\hat{v}\,\pi} \\
0 & \frac{k_t}{J_e} & 0 & -\frac{b_m + \frac{2\,F_{\max}\,r^2 \tan\left(\frac{\pi\,k}{2}\right)}{\hat{v}\,\pi}}{J_e} & \frac{2\,F_{\max}\,r \tan\left(\frac{\pi\,k}{2}\right)}{J_e\,\hat{v}\,\pi} & \frac{F_{\max}\,r\,w \tan(\frac{\pi\,k}{2}}{J_e\,\hat{v}\,\pi} \\
0 & 0 & \frac{2\,F_{\max}\,r \tan\left(\frac{\pi\,k}{2}\right)}{m_C\,\hat{v}\,\pi} & \frac{2\,F_{\max}\,r \tan\left(\frac{\pi\,k}{2}\right)}{m_C\,\hat{v}\,\pi} & -\frac{4\,F_{\max} \tan\left(\frac{\pi\,k}{2}\right)}{m_C\,\hat{v}\,\pi} & 0 \\
0 & 0 & -\frac{F_{\max}\,r\,w \tan\left(\frac{\pi\,k}{2}\right)}{J_C\,\hat{v}\,\pi} & \frac{F_{\max}\,r\,w \tan\left(\frac{\pi\,k}{2}\right)}{J_C\,\hat{v}\,\pi} & 0 & -\frac{F_{\max}\,w^2 \tan(\frac{\pi}{2}}{J_C\,\hat{v}\,\pi} \\
0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0
\end{matrix}
$$

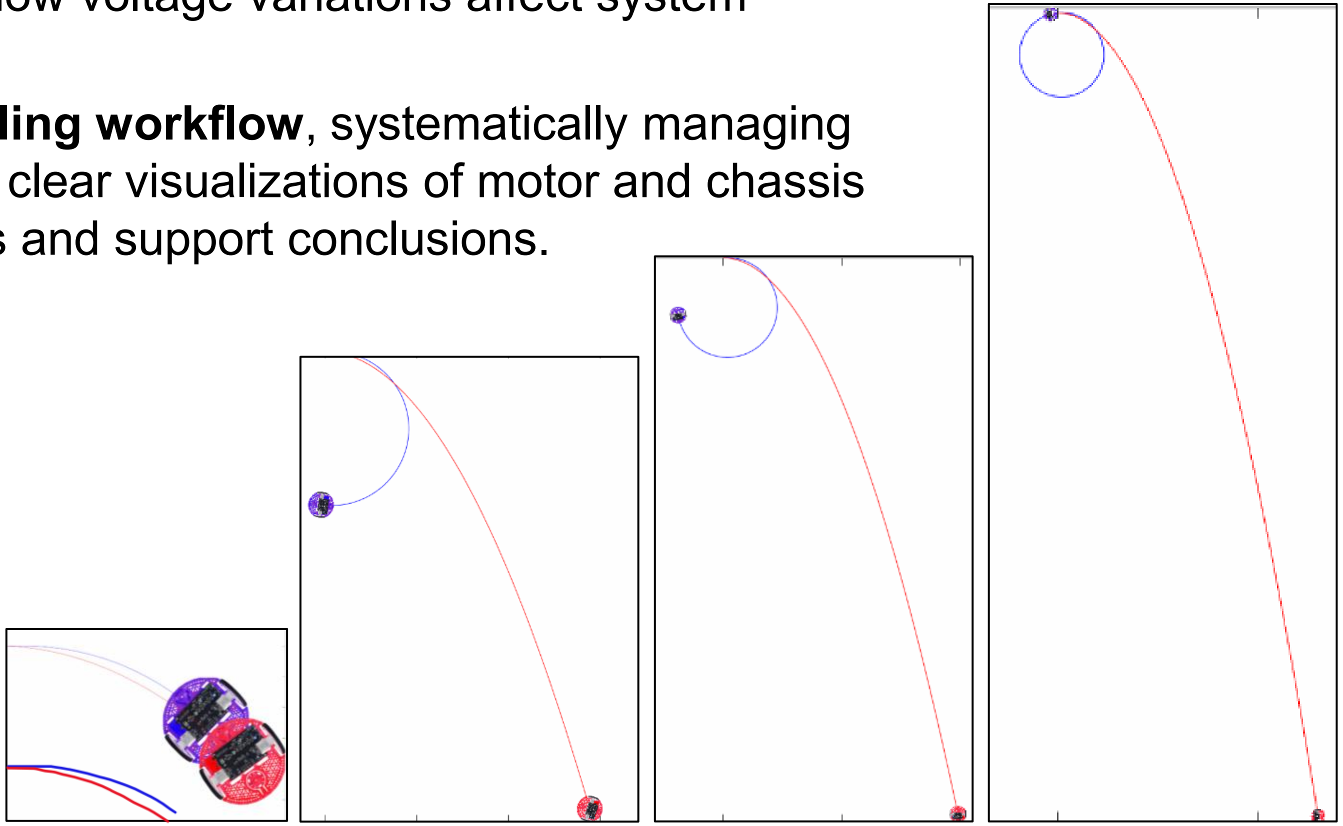
Jacobian Matrix with System Equations

System Dynamics – Linear vs Nonlinear Models

- **Simulated and validated robot performance**, comparing linearized and nonlinear models with experimental results to evaluate trajectory accuracy, identify deviations, and understand how voltage variations affect system response.
- **Organized and documented modeling workflow**, systematically managing code and input scenarios, producing clear visualizations of motor and chassis behavior to track performance trends and support conclusions.



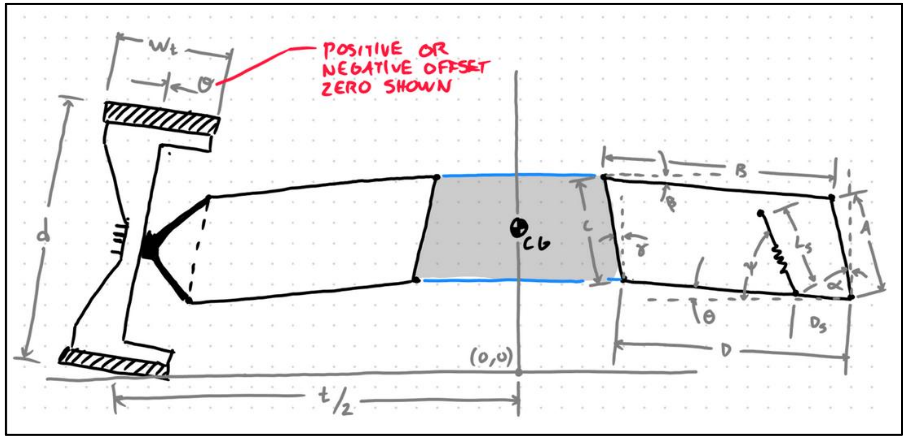
Simulink System for 3 Voltage Cases



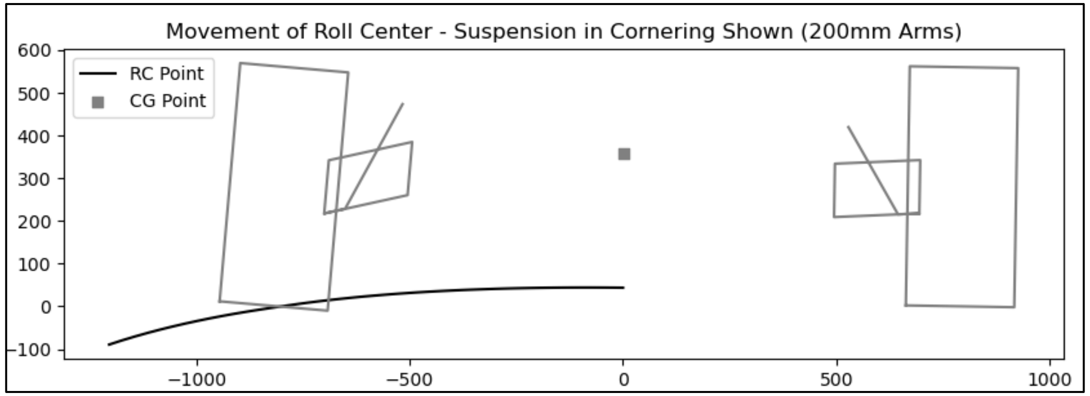
Linear (Red) vs Nonlinear (Blue) Simulated Paths

Suspension Geometry Research Project

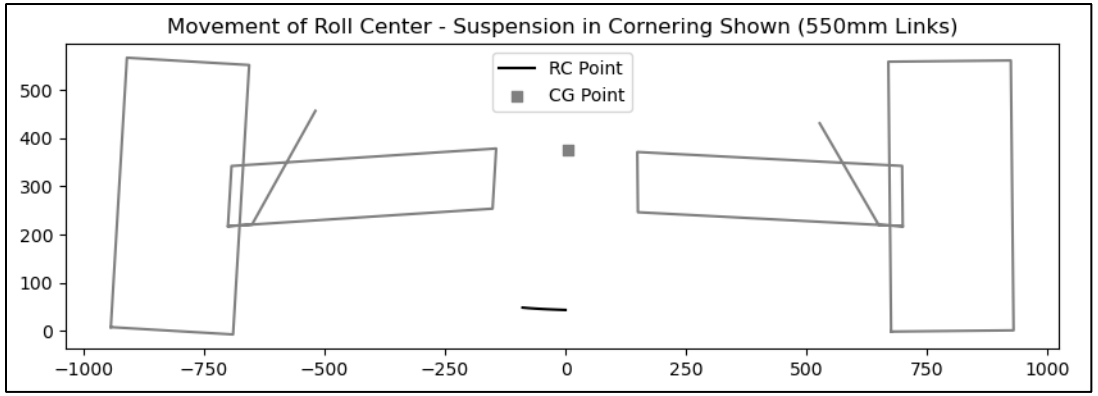
- **Analyzed double wishbone suspension geometry**, evaluating how control arm length and angle affect roll center migration, jacking forces, and track width changes during cornering.
- **Developed and utilized a Python kinematic model** to compute instantaneous centers, roll center positions, and lateral displacements across varied geometries, performing **residual/error checks** to identify unrealistic results.



Kinematics Setup for Scenario



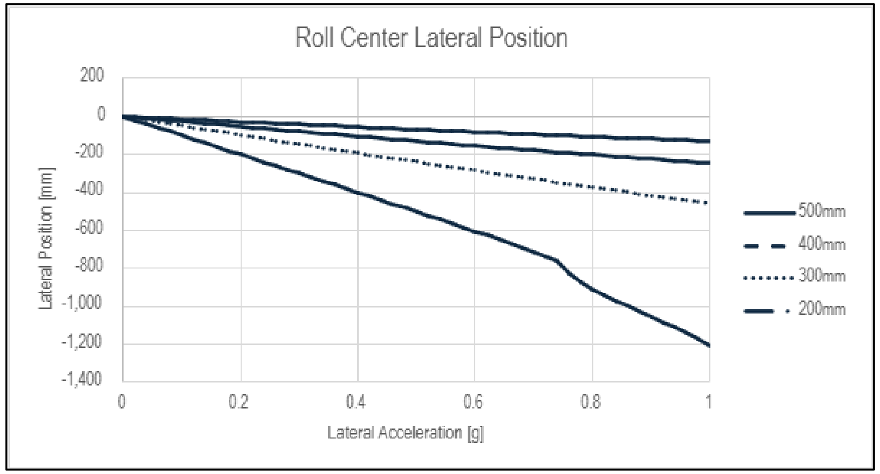
200mm Link Length Scenario



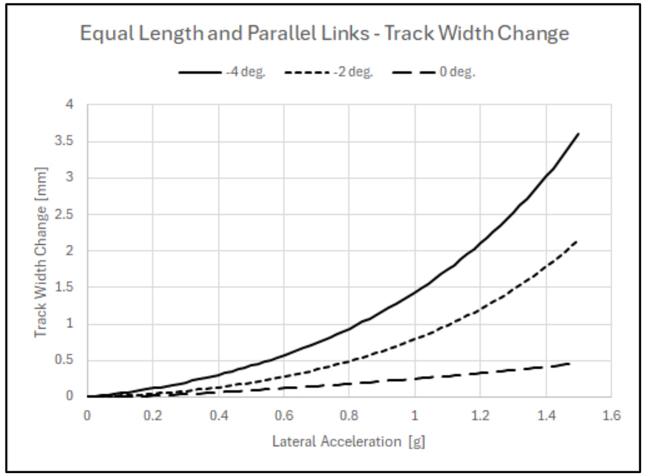
500mm Link Length Scenario

Suspension Geometry Research Project

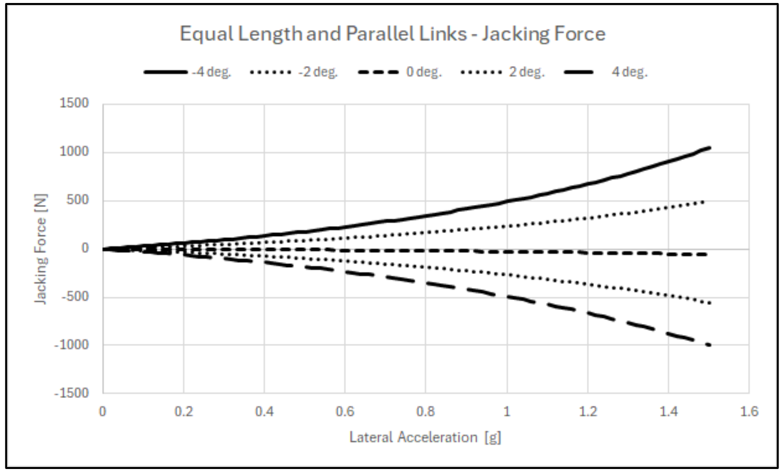
- **Investigated control arm angle effects**, finding that near-horizontal angles (~0°) minimized jacking forces and track width variation, with a small 0.05° offset required to prevent division-by-zero errors in the model.
- **Assessed control arm length impact**, showing longer arms (~550 mm) reduced roll center movement (~120 mm at 1 g) compared to short arms (~200 mm, ~1200 mm RC rise), improving vehicle stability and ride quality.
- **Interpreted results for vehicle performance**, concluding that short, highly angled arms cause excessive vertical and lateral roll center migration, leading to increased body roll, reduced aerodynamic consistency, and diminished tire contact patch grip.



Roll Center



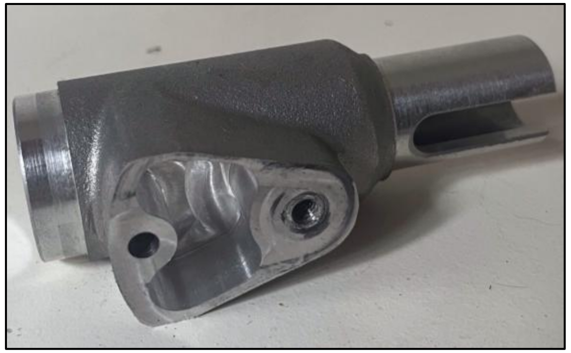
Track Width Change



Jacking Force

Air Motor Project

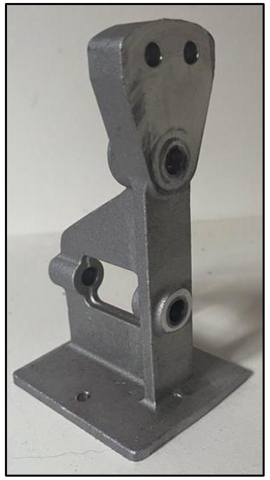
- **Achieved the fastest-performing compressed-air motor in the class**, optimizing piston–crank–flywheel alignment, component selection, and precision polishing to reduce mechanical resistance and maximize speed.
- **Produced a functional compressed-air motor** within a batch production workflow, emphasizing process planning, fixture setup, and coordination for multi-operator throughput.
- **Performed machining operations**, including CNC milling, lathe turning, drilling, and casting of aluminum components, followed by polishing to minimize friction.
- **Conducted assembly checks and tolerance verification**, ensuring proper fit and alignment of shaft-to-bore connections and smooth operation of the piston–crank–flywheel mechanism.



Cast and CNC

Brass (CNC)

Cast and Lathe

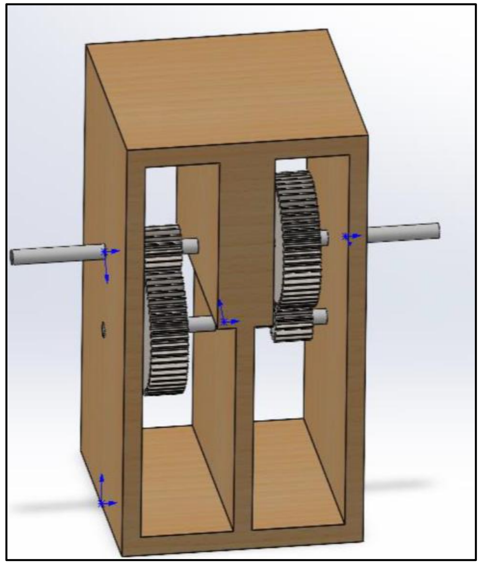


Cast and CNC

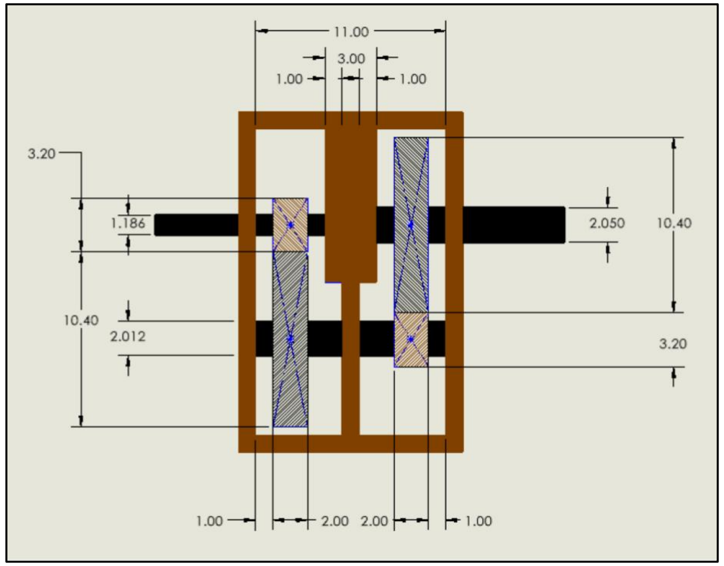
Assembled Air Motor

Power Transmission Gear Project

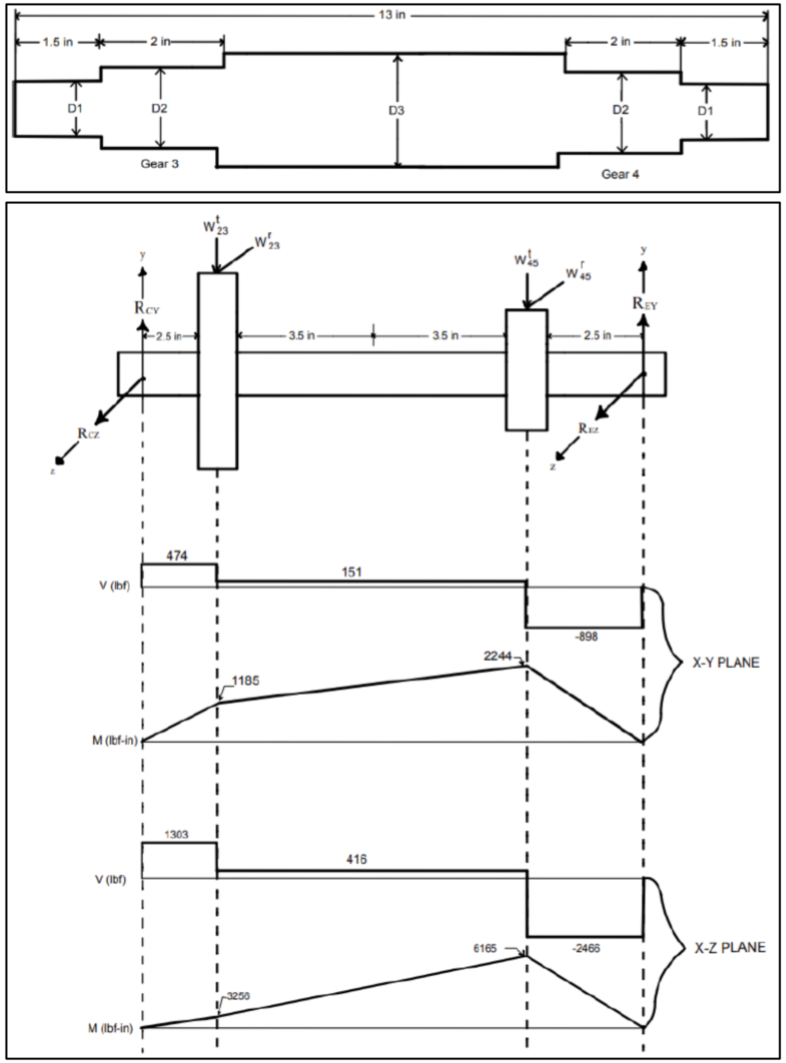
- **Designed a two-stage compound spur gear reduction system**, achieving **input speed 1155 RPM**, **output speed 106 RPM**, **26 HP delivered**, and **12,480-hour bearing life** under heavy-duty loading conditions.
- **Performed detailed gear and bearing analysis**, including gear tooth count/size selection, face width, bending and contact stress, deflection, and lifespan verification via free-body and shear/moment diagrams, validated using *Shigley's Mechanical Engineering Design.*



CAD Mockup



Layout Drawing



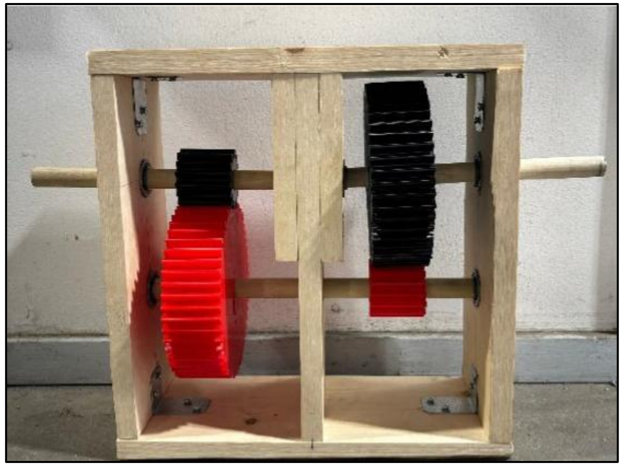
Shear & Moment Diagram: Main Shaft

Power Transmission Gear Project

- **Developed and maintained an integrated Excel spreadsheet**, consolidating calculations for gears, bearings, and shafts as a shared reference for the team.
- **Modeled gears and shafts in SolidWorks with parameterized geometry**, 3D printed prototype gears, and assembled the gearbox to validate reduction ratio and power transmission.
- **Delivered a complete project package**, including a design report, poster, and functioning prototype, demonstrating accurate gear ratios, reliable power transmission, manufacturability, and overall system performance under heavy-duty loading. Coordinated integration of analysis, CAD modeling, and prototyping to ensure the final design met all specifications.

	Treatment	Diameter (in)	S_c (kpsi)	S_t (kpsi)	η_t	η_c
Gear 2	Grade 1, carburized and hardened steel	3.2	180	55	2.04	1.22
Gear 3	Grade 1, carburized and hardened steel	10.4	180	55	3.95	1.4
Gear 4	Grade 3, carburized and hardened steel	3.2	275	75	1.42	1.34
Gear 5	Grade 3, carburized and hardened steel	10.4	275	75	2.57	1.61
* S_c = Contact Strength, S_t = Bending Strength						

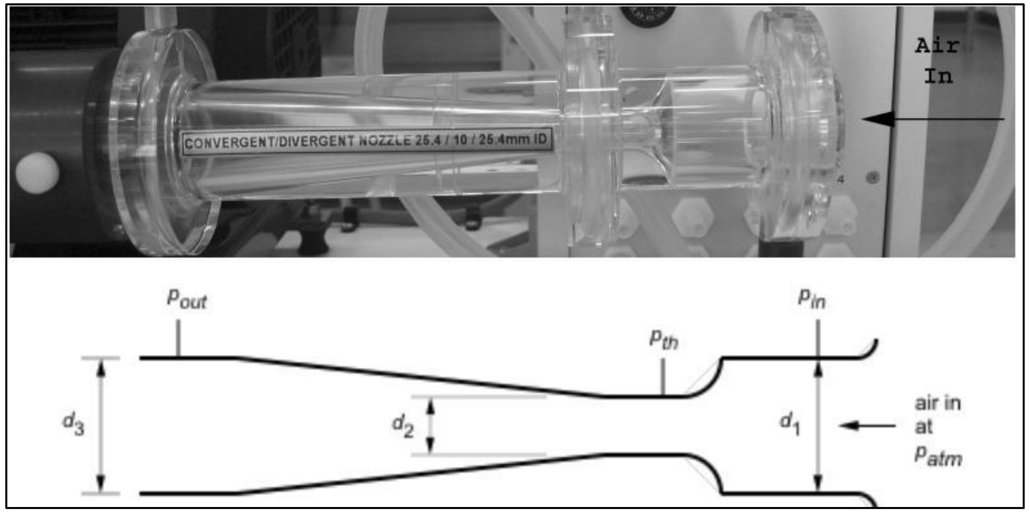
Gear Specifications



Physical Prototype

Fluids Lab Work

- **Tested nozzle flow behavior** using a compressor-driven setup, measuring inlet, throat, and outlet pressures to capture **Mach ≈ 0.3 through Mach 1** (choked flow).
- **Converted measured pressures to absolute values** and calculated Mach number, pressure ratios, and mass flow rates for both compressible and incompressible models.
- **Coded iterative solutions in EES**, computing throat pressure ratios and Mach numbers, generating **smooth plots (N=100)** and concise **data tables (N=25)** for analysis.



Flow Setup

Modeling.

$$C = \sqrt{k} \cdot \left[\left[\frac{2}{k+1}\right]^{\left[\frac{k+1}{2 \cdot (k-1)}\right]}\right]$$

$$\dot{m}_{chcked} = C \cdot A_{th} \cdot \frac{P_o}{\sqrt{R \cdot T_o}}$$

$$N = 25$$

$$\dot{m}_{m,i} = \left[\frac{i-1}{N}\right] \cdot \dot{m}_{chcked} \qquad \text{(for } i = 1 \text{ to } N\text{)}$$

Incompressible Model.

$$Pr_{th,inc,i} = 1 - \frac{\left[\frac{\dot{m}_{m,i}}{A_{th}}\right]^2}{2 \cdot \rho_o \cdot P_o} \qquad \text{(for } i = 1 \text{ to } N\text{)}$$

$$Ma_{th,inc,i} = \frac{\frac{\dot{m}_{m,i}}{A_{th}}}{\sqrt{k \cdot \rho_o \cdot P_o \cdot Pr_{th,inc,i}}} \qquad \text{(for } i = 1 \text{ to } N\text{)}$$

Compressible Model.

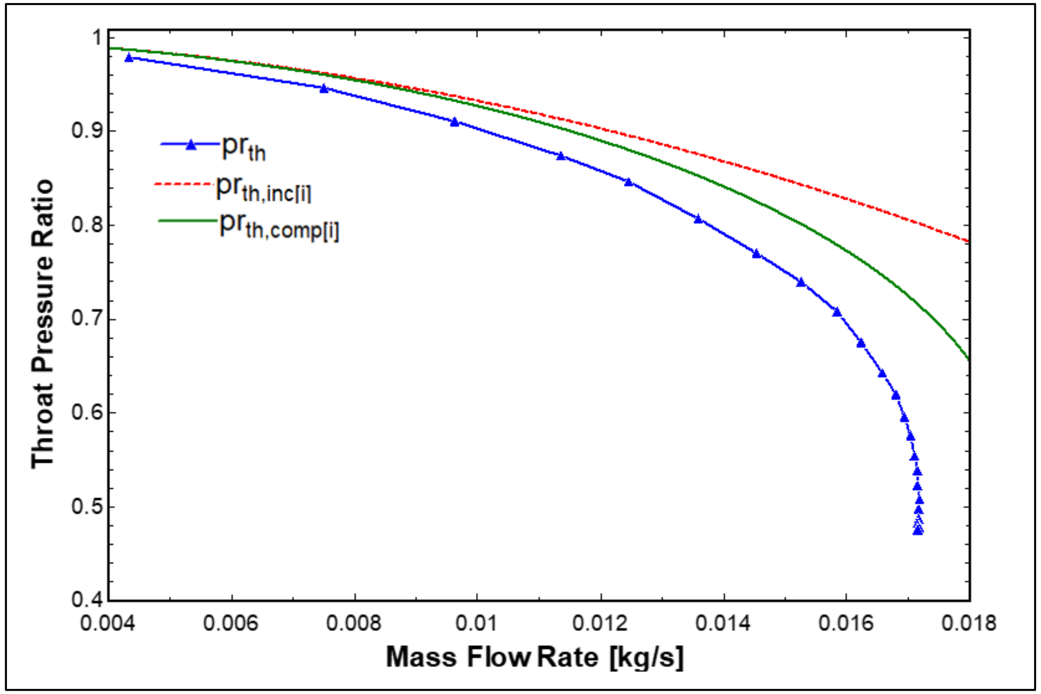
$$Pr_{th,comp,i} = \frac{1}{\left[1 + \left[\frac{k-1}{2}\right] \cdot Ma_{th,comp,i}^{2}\right]^{\left[\frac{k}{k-1}\right]}} \qquad \text{(for } i = 1 \text{ to } N\text{)}$$

$$Ma_{th,comp,i} = \frac{\frac{\dot{m}_{m,i}}{A_{th}}}{\sqrt{k \cdot \rho_o \cdot P_o \cdot Pr_{th,comp,i}^{\left[\frac{k+1}{k}\right]}}} \qquad \text{(for } i = 1 \text{ to } N\text{)}$$

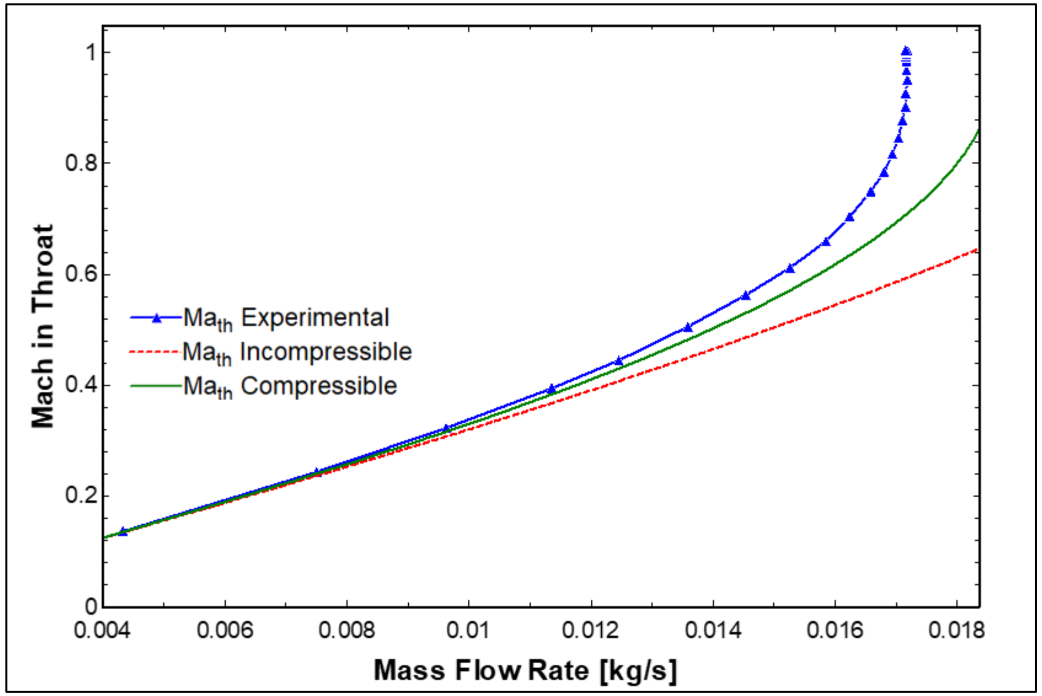
Equation Snippet in EES

Fluids Lab Work

- **Compared theoretical vs. experimental results**, showing divergence from incompressible assumptions at **Mach ≈ 0.3** and confirmation of choking at **Mach 1 ($\dot{m}$ ≈ 0.018 kg/s)**.
- **Identified viscous effects** as the cause of lower experimental mass flow rates and throat pressure ratios compared to ideal isentropic theory.
- **Demonstrated integrated technical skills**, designing, executing, and analyzing a fluid dynamics experiment while combining theory, coding, and experimental data into one report.



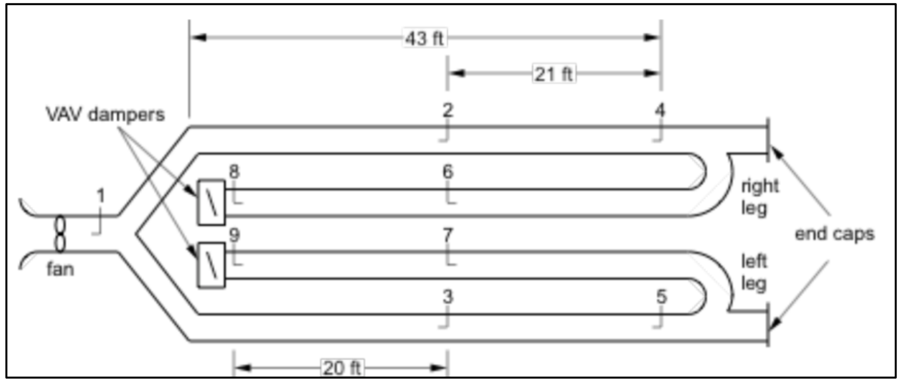
Compressible vs Incompressible in Pressure Ratio



Compressible vs Incompressible Mach Number

Additional Work - Courses

- **Microcontroller & Controls Programming:** Developed and tested PID, PD, and PI controllers using Java; applied **root locus analysis** to tune and optimize response.
- **Fluids & Experimental Projects:** Conducted lab experiments on pipe flow, converging-diverging nozzles, cylinders in uniform streams, boundary flow behavior, and axial fans.
- **TIG & MIG Welding Practice:** Practiced welding techniques to fabricate small projects, including a metal dice.



Axial Fan Experiment

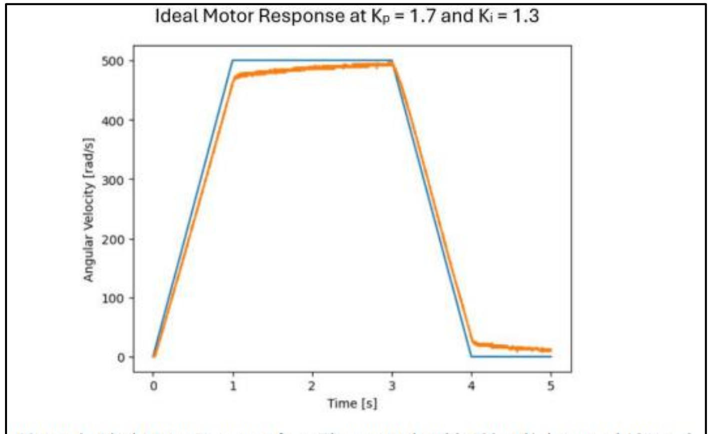
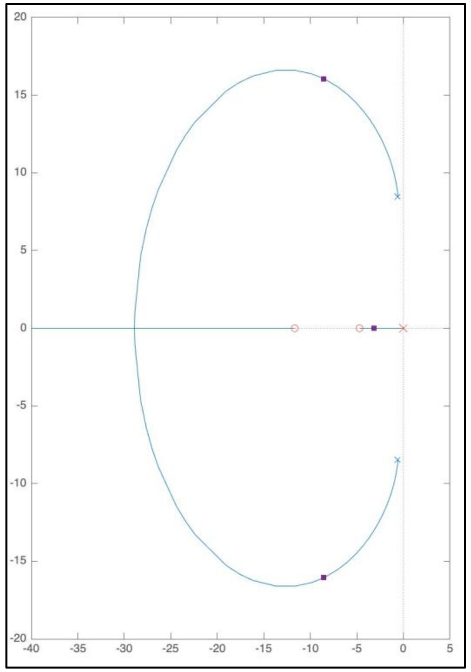


Figure 2: Ideal Motor Response from Thonny Code with 500 rad/s input and 12V and 100% saturation with varied Proportional and integral gains to match ideal speed profile.

PI Motor Control Analysis



Root Locus Analysis

Additional Work - Personal

- **Rowing Lead Boatwright:** Repaired and maintained aluminum riggers, stripped and painted oars, replaced skegs, assisted in acquiring boats, and led teams to rig and derig for competitions; consistently scored competitively at regattas, made **WIRAs both years**, achieved the **fastest erg times** on the women's team, and helped the women's A boat reach **the first finals in 50 years** for the revamped 2023 team.
- **DIY & Automotive Projects:** Maintained and upgraded personal car components, including thermostat, catalytic converter, and headlight assembly; bled the coolant system. **Saved over $5,500** through self-performed repairs.
- **Archery Project:** Built a functional PVC longbow with a **50 lb draw weight**.

Crew Team

Oar Maintenance

New Headlights

Front and Rear Catalytic Replacement