



University of Idaho

College of Engineering

Design Review

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Objective

- When traveling over bumpy surfaces with an unloaded forklift, the carriage and the forks tend to bounce violently. This creates a considerable amount of noise and increases wear on the system. The violent gyration can also cause an operator to spill what they are carrying. Our goal is to reduce the bounce of the carriage and the negative side effects ascertaining to carriage bounce.

Value Proposition

- Develop a carriage damping system to reduce/eliminate carriage bounce and vibration.

- Carriage bounce causes problems
 - Noise
 - Load instability
 - Increased wear
- We will use a brake mechanism to hold the carriage steady
 - Stop or reduce the motion of the carriage relative to the mast
- We will use a Fork clamp to reduce noise from rattling forks.
- reduce losses associated with unstable loads



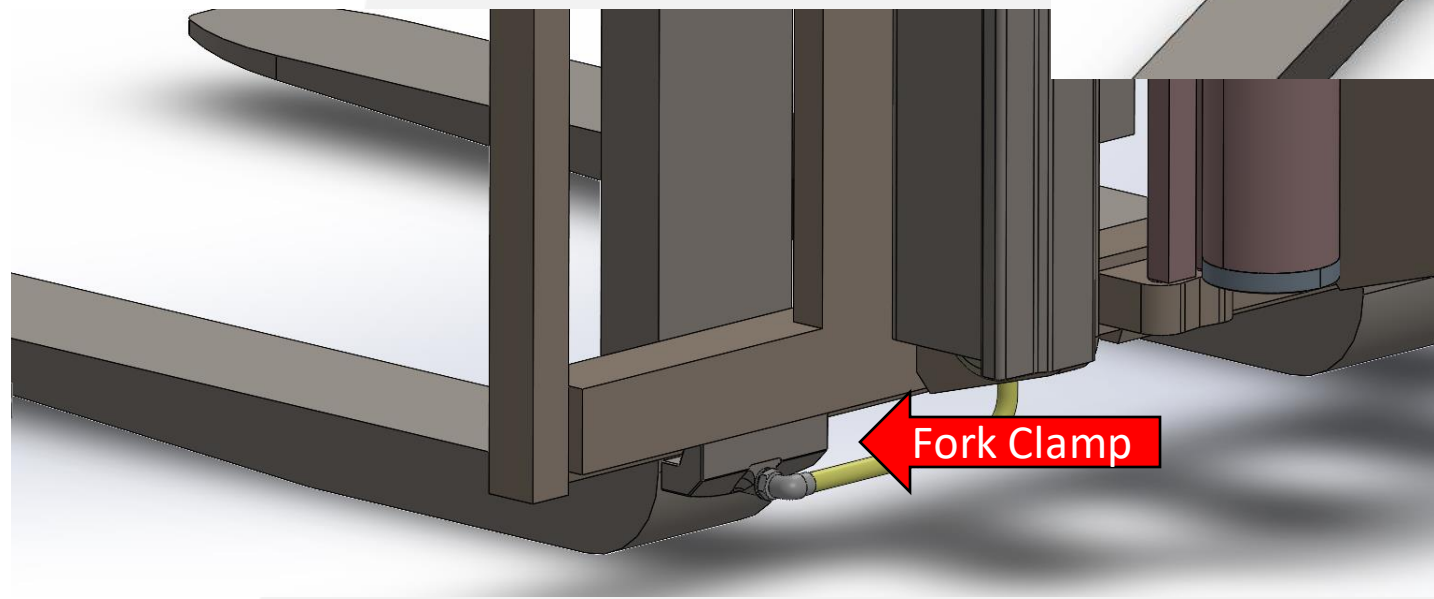
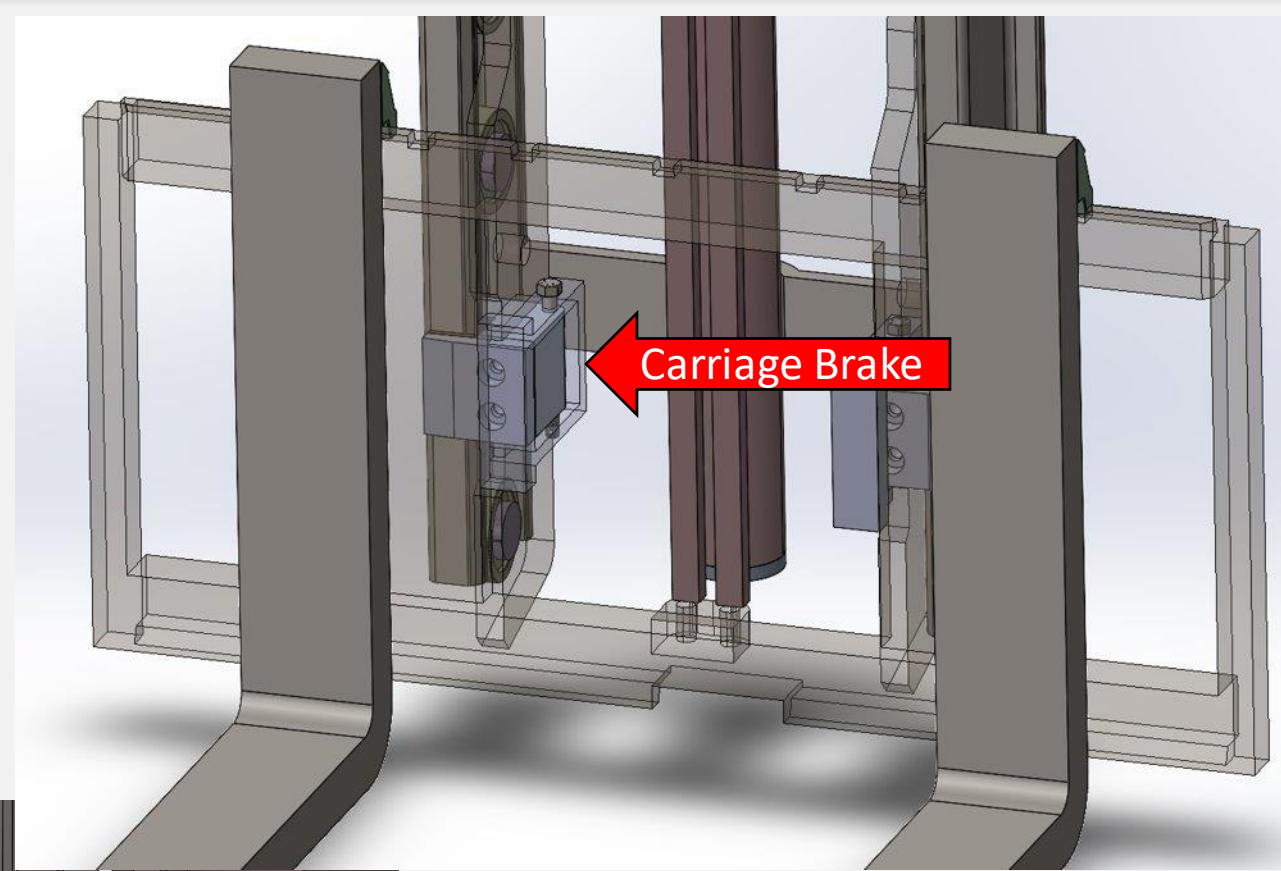


Design requirements

- Effective on a variety of surfaces
 - Broken pallets, 2x4's, bumpy gravel lots, railroad tracks, etc.
- Within hydraulic pressures forklift is capable, ~2500 psi
- Work within \$4000 budget (\$2300 for materials, etc.)
- Scalable- Concept applicable to low and high-capacity trucks
- Manufacturable, fits on to current forklift design with minor changes
- Durable in outdoor conditions

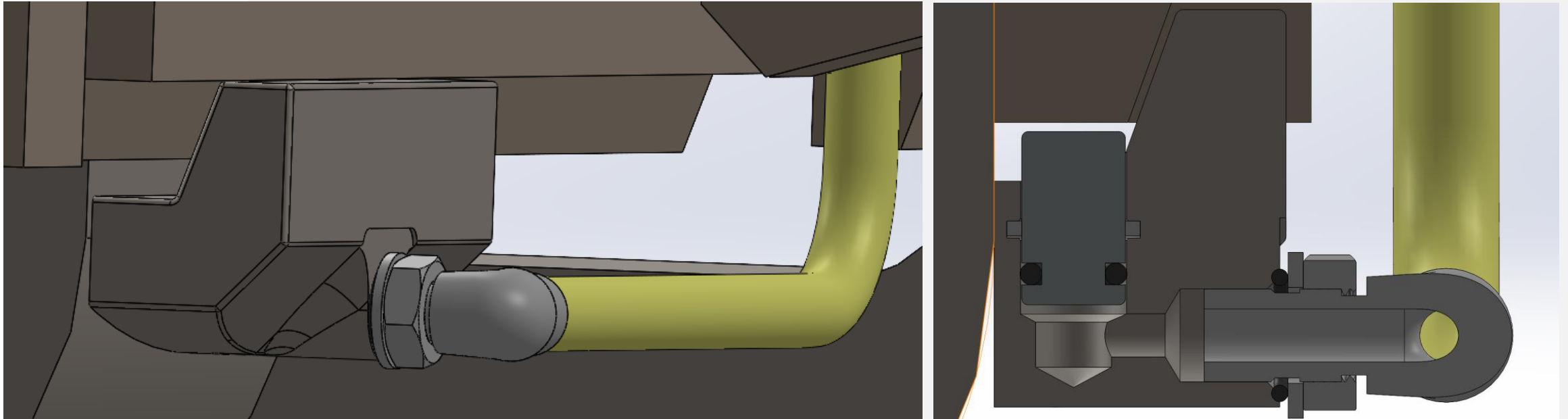


Finalized Design

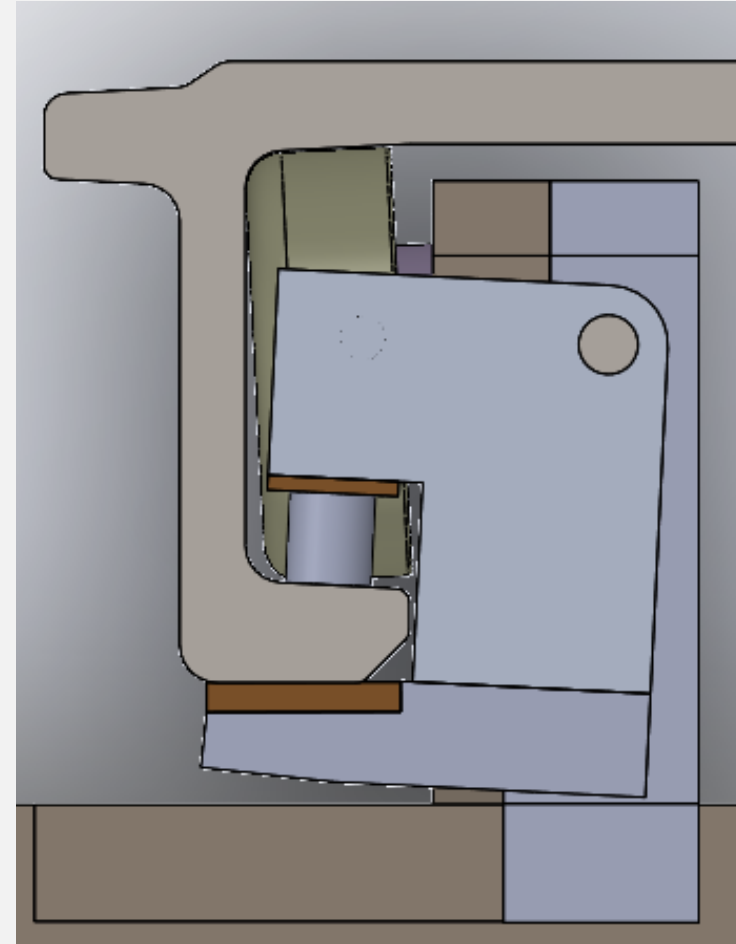
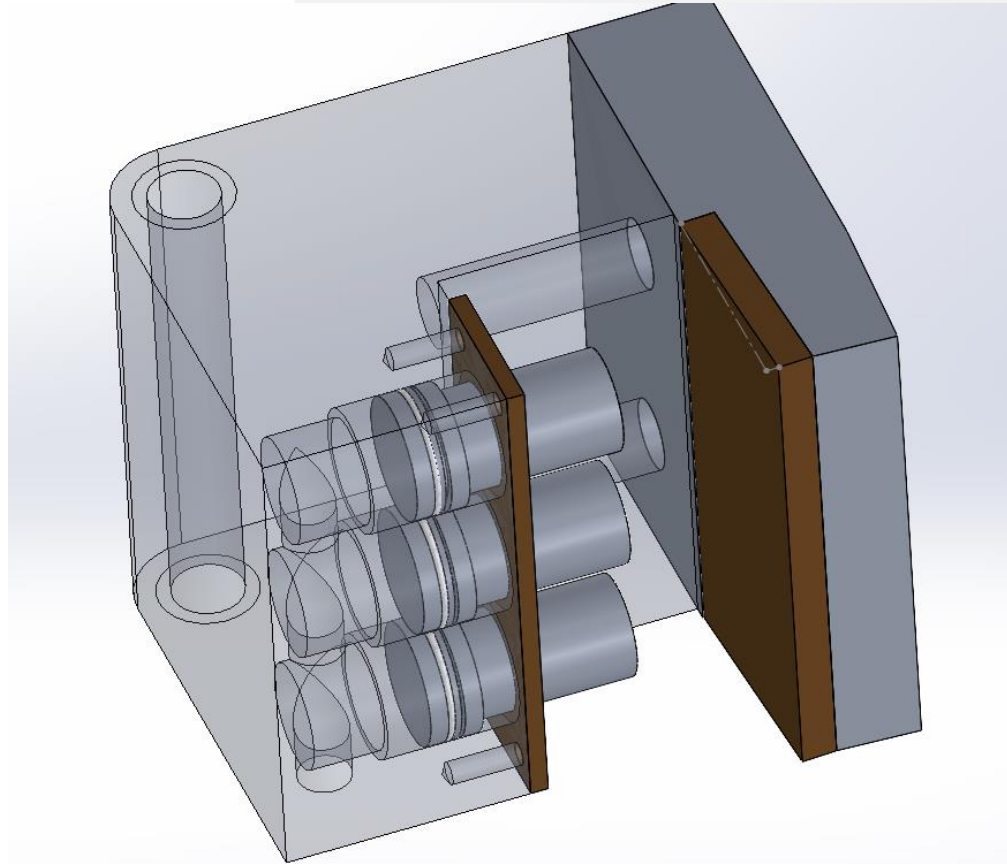




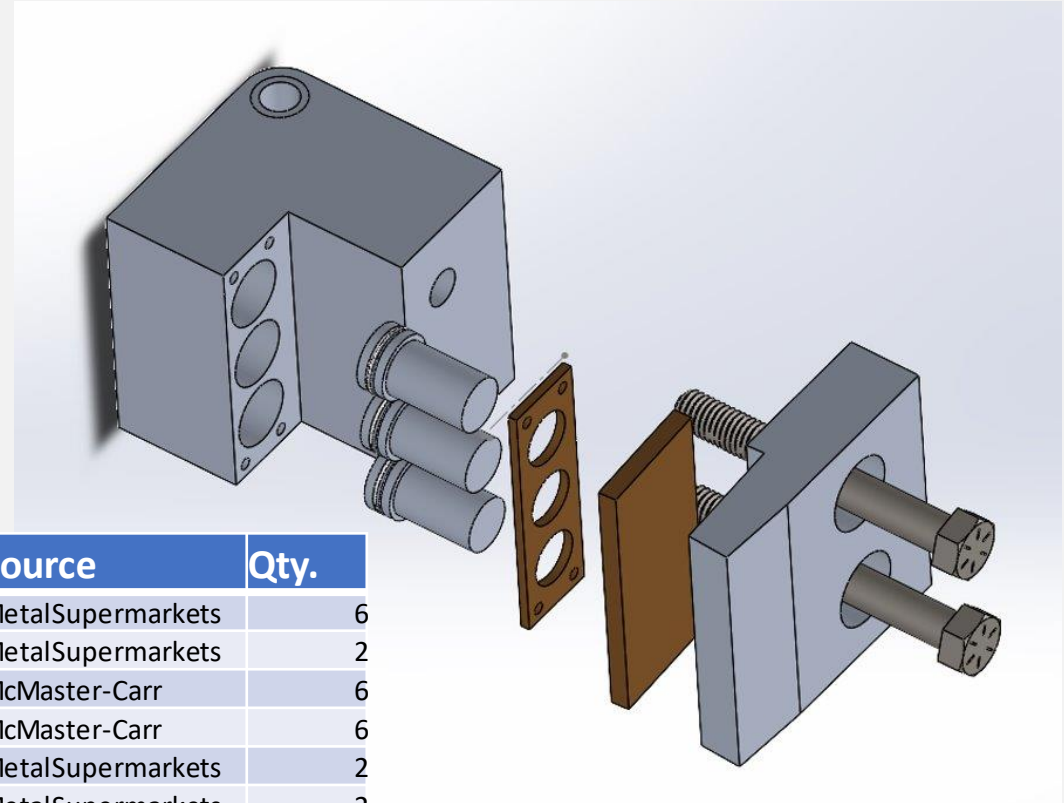
Finalized Design- Fork Clamp



Finalized Design-Brake



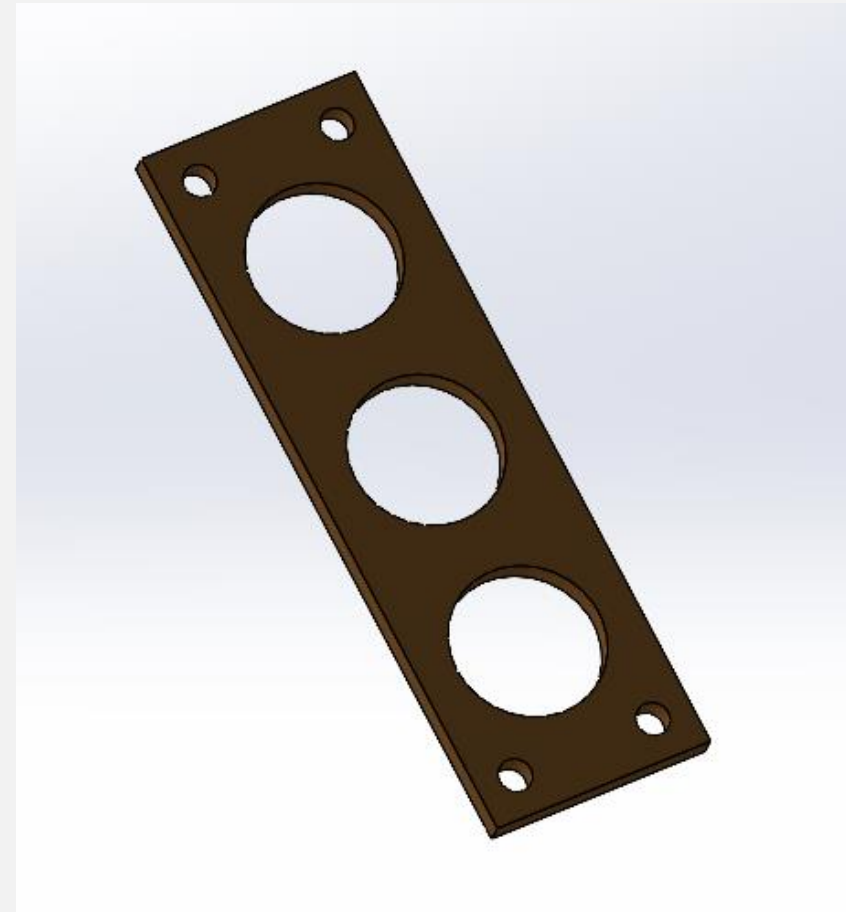
Manufacturing Plan



Part	Made Vs Bought	Part #	Material	Cost	Source	Qty.
Piston	Made	01-01	6061 AL	TBD	MetalSupermarkets	6
Cylinder	Made	01-02	6061 AL	TBD	MetalSupermarkets	2
Snap Ring	Bought	9560K450	PTFE	13.10 Per 50 pk	McMaster-Carr	6
O-Ring	Bought	94115K018	Neoprene	5.05 Per 100 pk	McMaster-Carr	6
Brake Pad	Made	01-03	6061 AL	TBD	MetalSupermarkets	2
Retaining Plate	Made	01-04	Bronze	TBD	MetalSupermarkets	2
M4 Screws	Bought	92095A476	Steel	8.04 Per 100 pk	McMaster-Carr	8
M12 Bolts Class 10.9	Bought	97478A112	Steel	5.14	McMaster-Carr	4
M12 Pivot Bolt Grade 8	Bought	91257A561	Steel	6.04	McMaster-Carr	2
Thrust Bearing	Bought	3750K7	Iron Copper	2.75	McMaster-Carr	4
Grade 8 Locknut	Bought	90630A125	Steel	3.44 Per 10 pk	McMaster-Carr	4
Mil Spec Flat Washer	Bought	91922A307	Steel	9.32 Per 25 pk	McMaster-Carr	2
Retaining Ring	Bought	99142A350	Spring Steel	6.12 Per 50 pk	McMaster-Carr	2
Hex Nut	Bought	94846A520	Steel	6.22 Per 50 pk	McMaster-Carr	2
Tight Space Fitting 90 deg	Bought	6407T210	Steel	13.33	McMaster-Carr	2
Tight Space Fitting	Bought	6407T420	Steel	43.91	McMaster-Carr	2
Fork Piston	Made	02-01	Steel	TBD	MetalSupermarkets	2
Bottom Block	Made	02-02	Steel	TBD	MetalSupermarkets	2

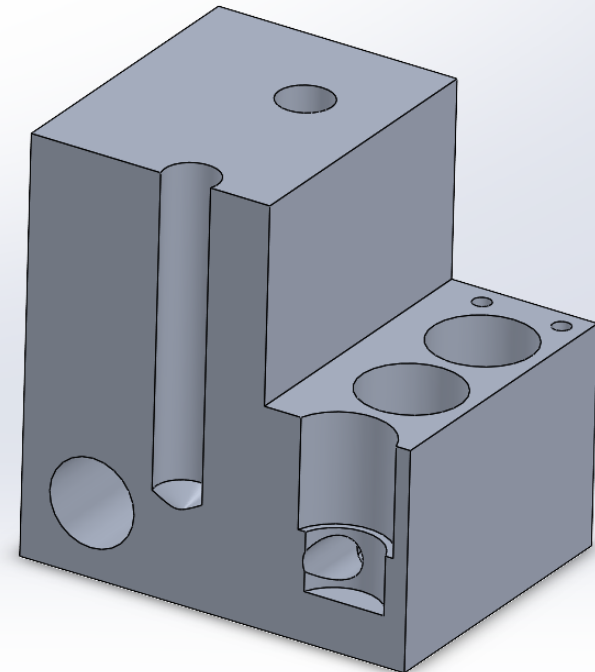
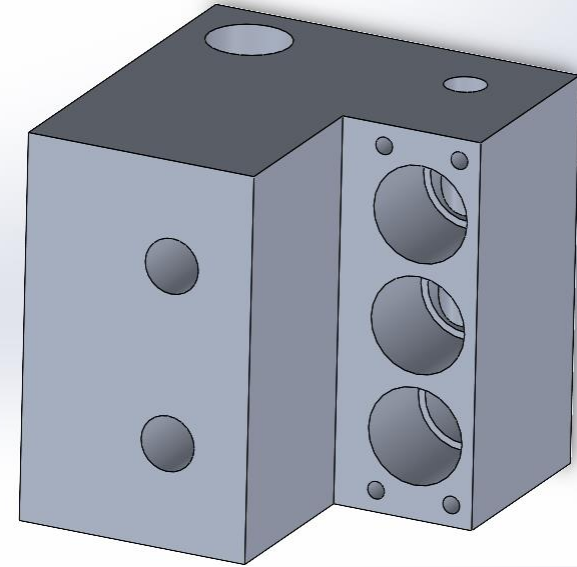
Spring Retaining Plate

- Used to hold piston return springs in place
- 1/16" air gap between pistons to prevent pistons from dragging and causing wear
- Held in place with 4 machine screws



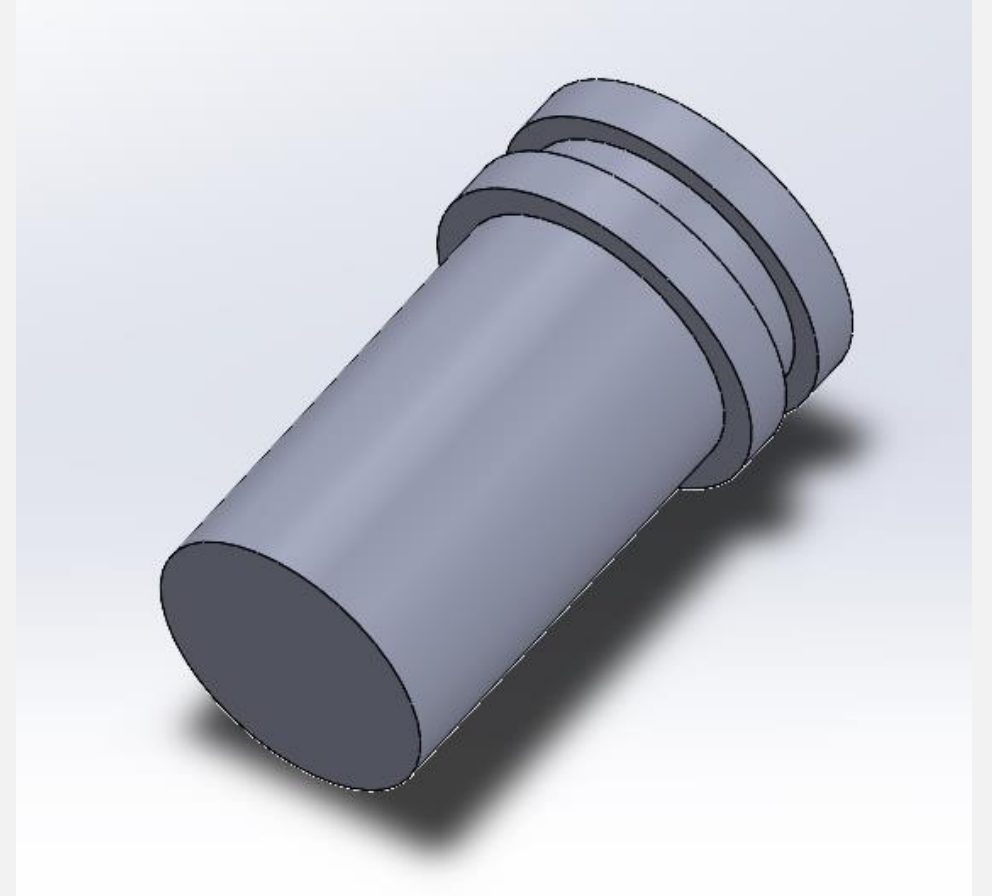
Cylinder

- Used 3 smaller pistons
- Rotates about corner
- Sleeved thrust bearings for support
- Made of Aluminum



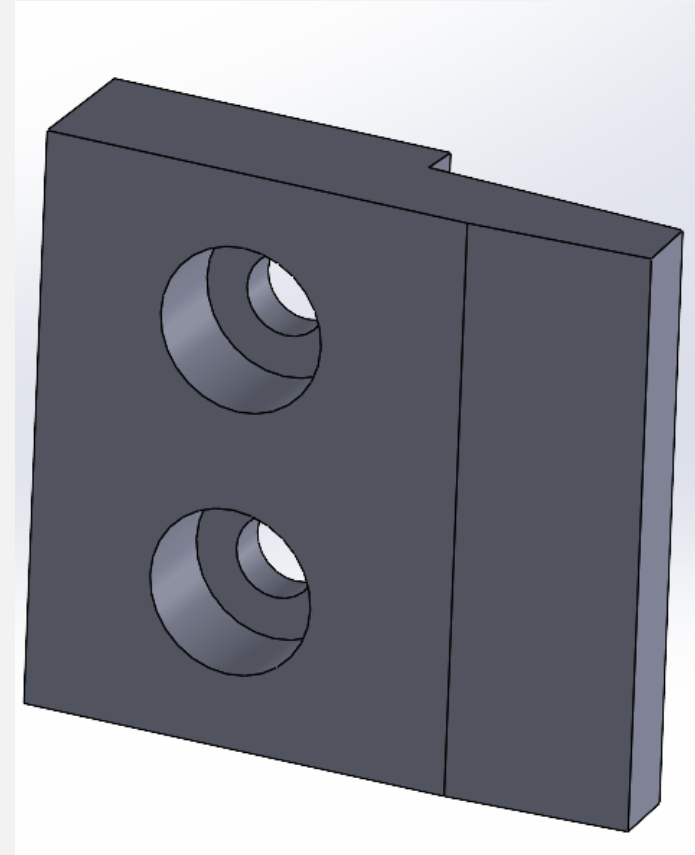
Pistons

- 7/8" effective hydraulic diameter
- Springs used to return piston to un-extended position
- Buna-N O-ring seals coupled with backup rings
- Machined from 6061 Aluminum

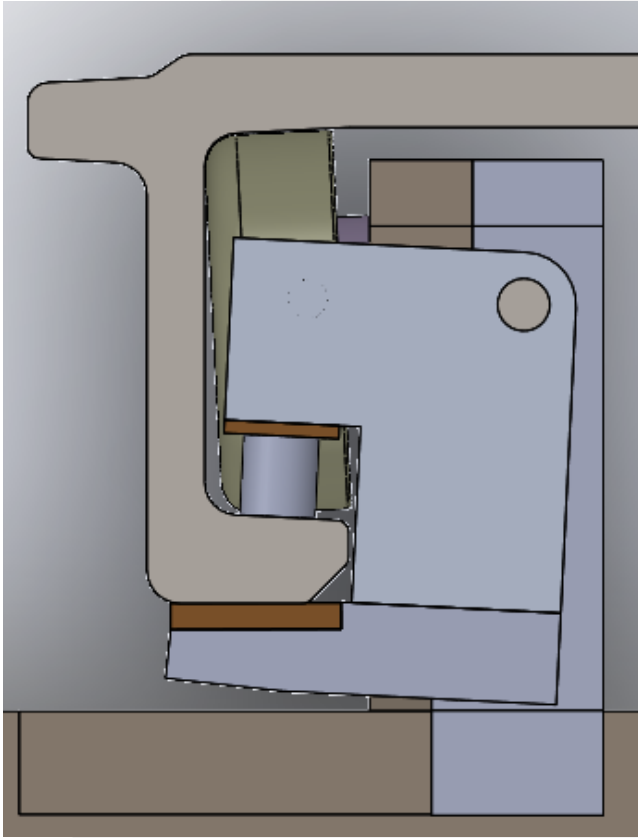


Brake Foot

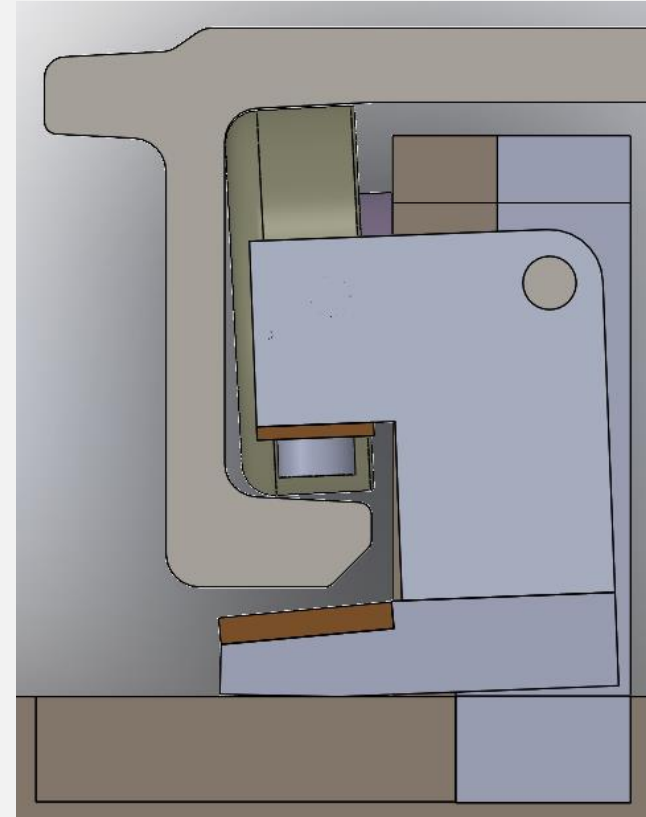
- Clamps outside of mast to hold carriage in place
- Holds replaceable brake pad
- Machined from 6061 Aluminum



Brake Positions



Clamped Position



Unclamped Position

Pivot Design

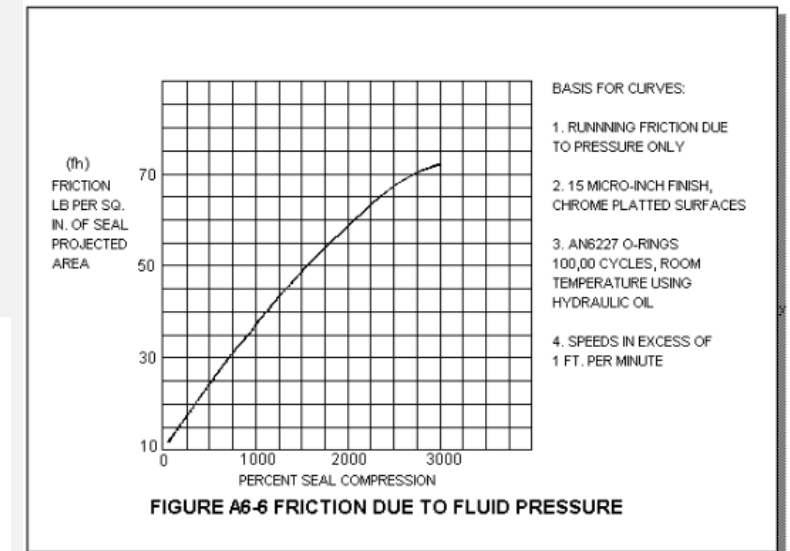
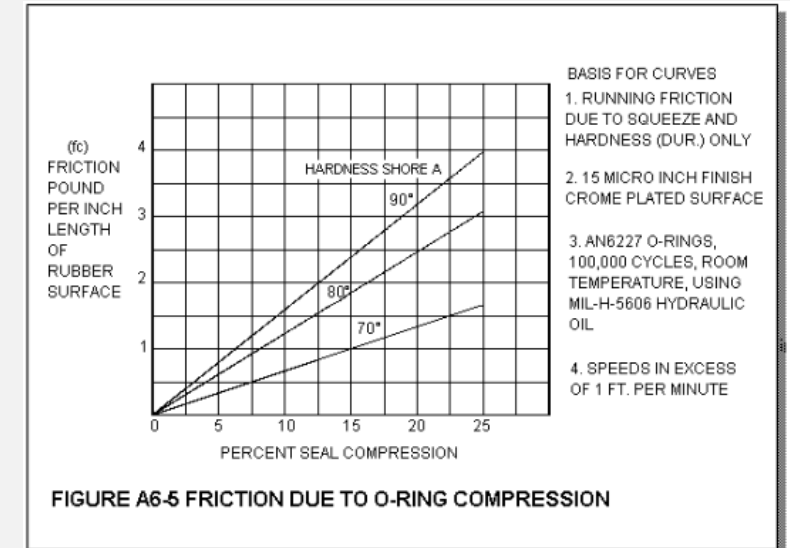
- Pivoting the brake when not in use provides $\frac{1}{4}$ " clearance along the length of the J-Channel mast so the brake pad does not wear in travel
- Allows for a deviation in thickness of J-channel
- Uses oil-impregnated bushings to reduce friction and wear



O-Rings

- 018 O-ring used for Carriage clamp
- Breakout Friction is approximately 3 times running friction
- Running Friction is $FH + Fc = fh \times Ap + fc \times Lp$
- Based on surface finish and final rubber, the force to overcome can range from 36 lbs to 72 lbs

$F =$ Total seal friction in pounds.
 $Fc =$ Total friction due to seal compression.
 $FH =$ Total friction due to hydraulic pressure on the seal.
 $fc =$ Friction due to O-ring compression obtained from Figure A6-5.
 $fh =$ Friction due to fluid pressure obtained from Figure A6-6.
 $Lp =$ Length of seal rubbing surface in inches for piston groove applications.
 $Lr =$ Length of seal rubbing surface in inches for rod groove applications.





Springs

- Assuming the pressure from the fluid is negligible there are several springs that could return the pistons
- Only between .12 to .25 inches of travel is needed

Product	CAD / Specs	Material	Wire Dia (in)	O. D. (in)	I. D. (in)	Free Length (in)	Total Coils	Rate (lb/in)	Ends	Suggested Max Load (lb)	Suggested Max Deflection (in)	Solid Length (in)	Standard Finish	Buy
<input type="checkbox"/> NN-24		Spring Steel - SPR	0.160	0.953	0.633	0.690	3.25	1,511.00	Closed/Ground - CG	124.000	0.080	0.52	Gold Irridite - GI	
<input type="checkbox"/> MM-98		Spring Steel - SPR	0.150	1.031	0.731	0.690	3.50	710.00	Closed/Ground - CG	96.000	0.130	0.53	Zinc - Z	
<input type="checkbox"/> KK-54		Spring Steel - SPR	0.140	0.968	0.688	0.780	4.00	486.00	Closed/Ground - CG	85.000	0.170	0.56	Gold Irridite - GI	
<input type="checkbox"/> 10942		Spring Steel - SPR	0.135	0.875	0.605	0.690	3.00	1,178.00	Closed/Ground - CG	84.000	0.070	0.41	Zinc - Z	
<input type="checkbox"/> 4235		Spring Steel - SPR	0.135	0.938	0.668	0.750	3.50	615.00	Closed/Ground - CG	79.000	0.130	0.47	Zinc - Z	
<input type="checkbox"/> 2817		Music Wire - MW	0.110	0.921	0.701	0.500	3.00	395.00	Closed/Ground - CG	63.000	0.160	0.33	Zinc - Z	
<input type="checkbox"/> S-3040		Stainless Steel - SST	0.130	0.938	0.678	0.750	3.50	451.00	Closed/Ground - CG	63.000	0.140	0.46	None - N	
<input type="checkbox"/> 3702		Spring Steel - SPR	0.120	0.875	0.635	0.660	4.00	346.00	Closed/Ground - CG	61.000	0.180	0.48	Zinc - Z	
<input type="checkbox"/> A11-51		Spring Steel - SPR	0.121	0.906	0.664	0.750	4.00	340.00	Closed/Ground - CG	61.000	0.180	0.47	Zinc - Z	
<input type="checkbox"/> AA-59		Spring Steel - SPR	0.120	0.859	0.619	0.630	4.00	369.00	Closed/Ground - CG	54.000	0.150	0.48	Gold Irridite - GI	
<input type="checkbox"/> AA-64		Spring Steel - SPR	0.130	0.890	0.630	0.630	4.00	468.00	Closed/Ground - CG	49.000	0.110	0.52	Zinc - Z	
<input type="checkbox"/> 2766		Spring Steel - SPR	0.110	0.906	0.686	0.500	3.00	417.00	Closed/Ground - CG	46.000	0.110	0.33	Zinc - Z	
<input type="checkbox"/> 1581		Spring Steel - SPR	0.105	0.859	0.649	0.630	3.50	272.00	Closed - C	41.000	0.150	0.47	Zinc - Z	



Brake Calculations

Diameter	Area	Pressure	Friction Coefficient	Friction Coefficient
0.875 in	0.60 in ²	2500 psi	0.16	0.61
			Steel on Steel greased	Steel on aluminum
Force per cylinder			Hold Force per brake pad	
1503 lb			2751 lb	
			Hold Force for 3 pistons	
			721 lb	
			Total Hold Force	
			6945 lb	



Bolt Calculations

- 12mm x 90mm bolts provide a Load Factor over 2
- Goodman Failure Criteria yields an infinite lifetime with a 1.27 Factor of Safety

Inputs			Design		
$E_m =$	2.00E+07 psi	Elastic modulus of the clamping material	$n =$	2	load factor
$E_b =$	3.00E+07 psi	Elastic modulus of the bolt material	$N =$	2	Number of bolts
$S_p =$	140687 psi	Proof strength of the bolt material	$F_i =$	13791 lbs	Initial load (per bolt)
$d =$	0.4700 in	bolt size	$T =$	1296 in-lb 108 ft-lb	Tightening Torque
$A_t =$	0.1307 in ²	Tensile area of the bolt	$F_m =$	-9652 lbs	(needs to be negative)
$L =$	3.54 in	Length of the bolt	$F_b =$	14750 lbs	
$l =$	3.00 in	grip length	$P =$	10195 lbs	Total Separation force
	0.540 in	extension of bolt beyond the grip	$P_N =$	5097 lbs	Separation force per bolt
	Need to make sure this is enough for a nut (or tapped threads)		This is the Proof load for each bolt: $P_{max} =$ 12217 lbs Load each bolt can carry Compare this to P_N (should be higher)		
Calculated			This is the force required for unclamping for each bolt: $P_o =$ 8493 Lbs Compare this to P_N (should be higher)		
$A_d =$	0.1735	Tensile area of the shank			
$l_{th} =$	1.19 in	Length of bolt threads (if bolt is < 6")			
$l_d =$	2.35 in	Length of shank			
	0.65 in	Length of threads in the grip			
	Need to make sure this is above zero.				
Results					
$k_b =$	1.62E+06 in-lb				
$k_m =$	6.99E+06 in-lb				
$C =$	0.188				
$1-C =$	0.812				

Need to use $\tau = VQ/Ib$ to get the shear stress, but this is likely very small.

von Mises 112853 psi

Validation Plan

- FEA
- Strain gauge measurements
- Full-scale, functional prototype
- Installed on a forklift carriage

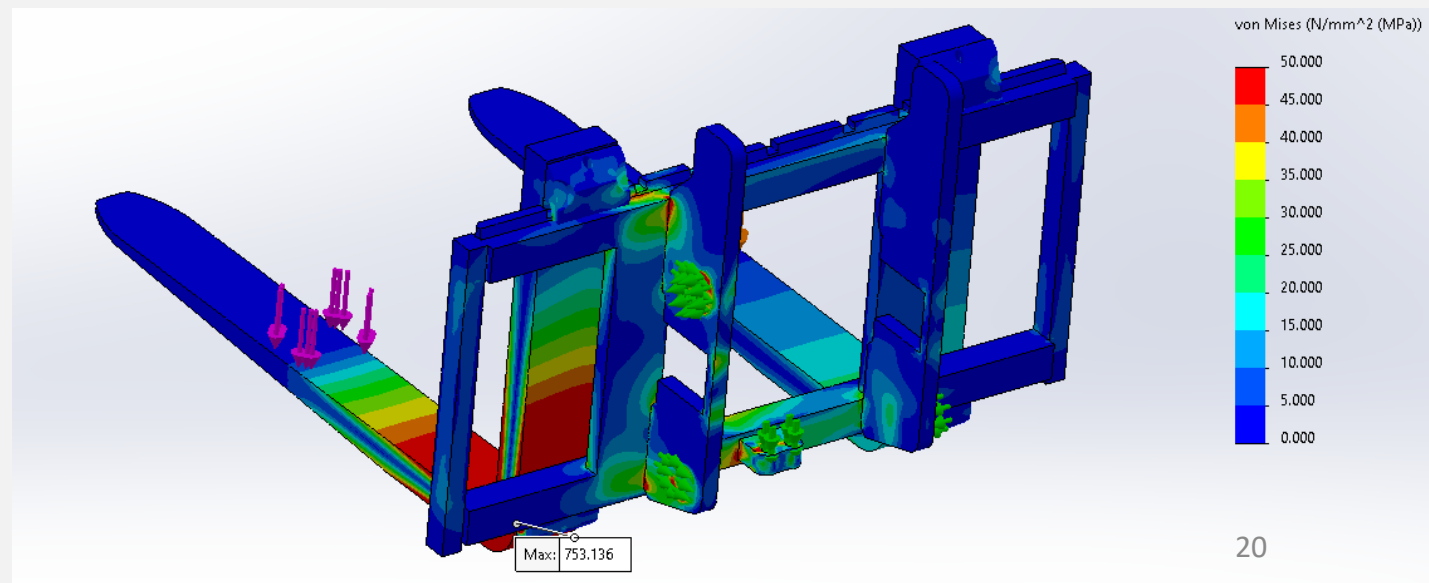
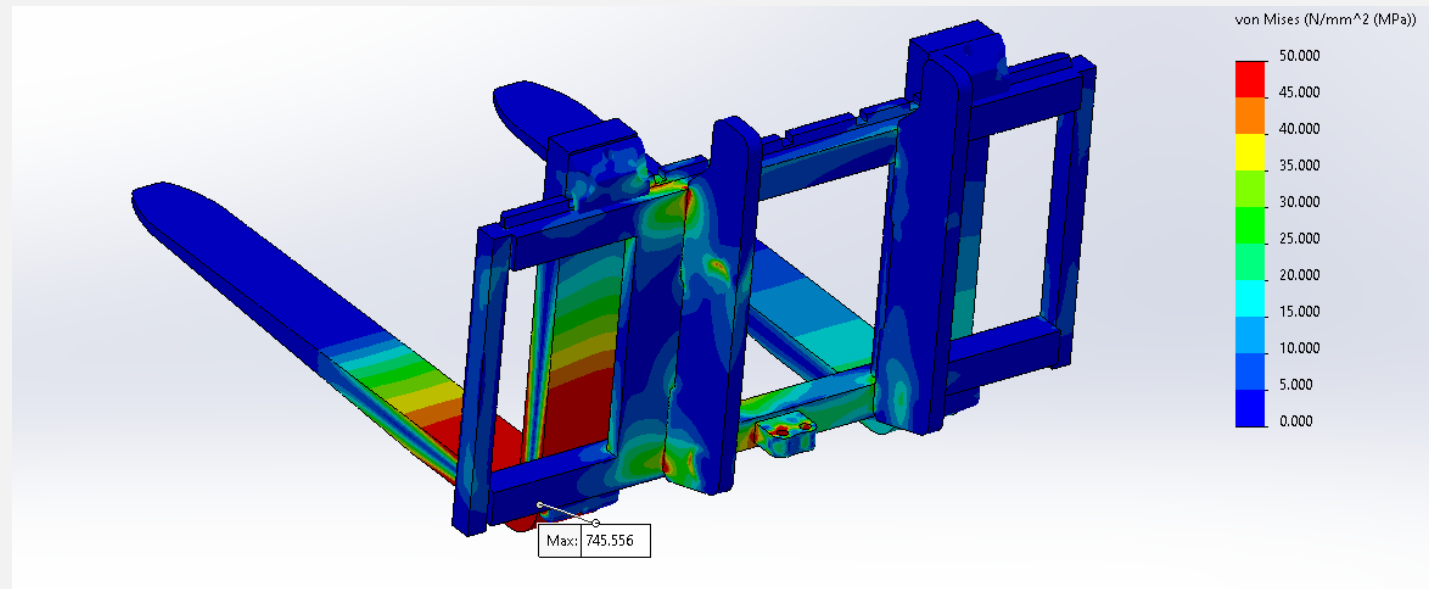




Carraige FEA

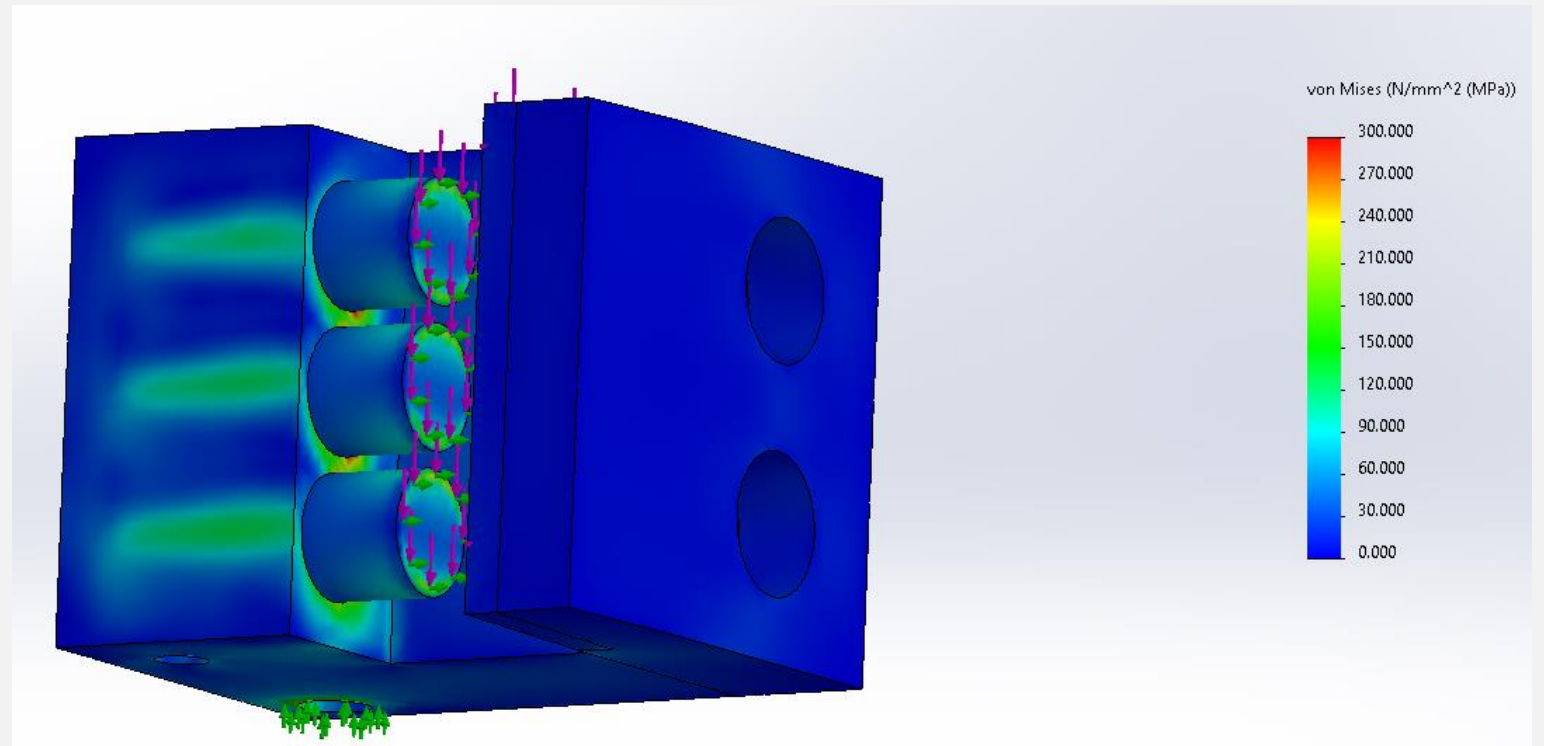
Stress Test Results

Config	Stress (Mpa)
Base	56.0
	74.3
	48.8
60.0	
Box	32.6
	57.5
	49.7
64.6	
Hole	50.4
	58.8
	63.2
	70.2



Cylinder FEA

- Tested using max holding force
- Plan to account for bolt pre-load
- Need to rework control volume



Data Collection

- What?
 - Inertial load determination
- Why?
 - Design Validation
- How?
 - Accelerometers
 - Strain Gauge



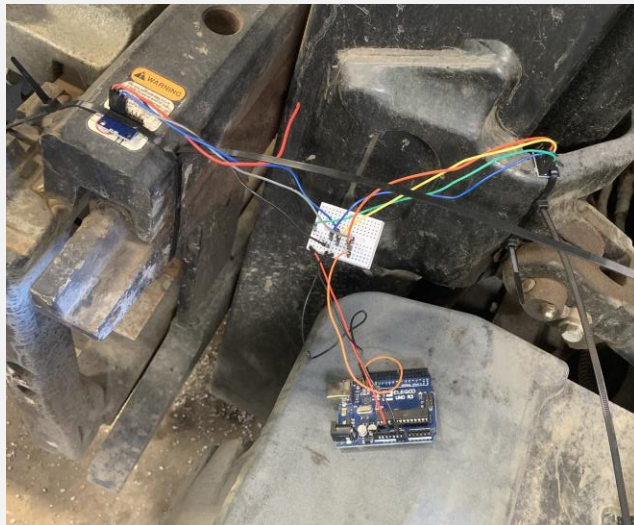
Accelerometer Data Collection

Limitations:

- I2C protocol noise
- Collisions

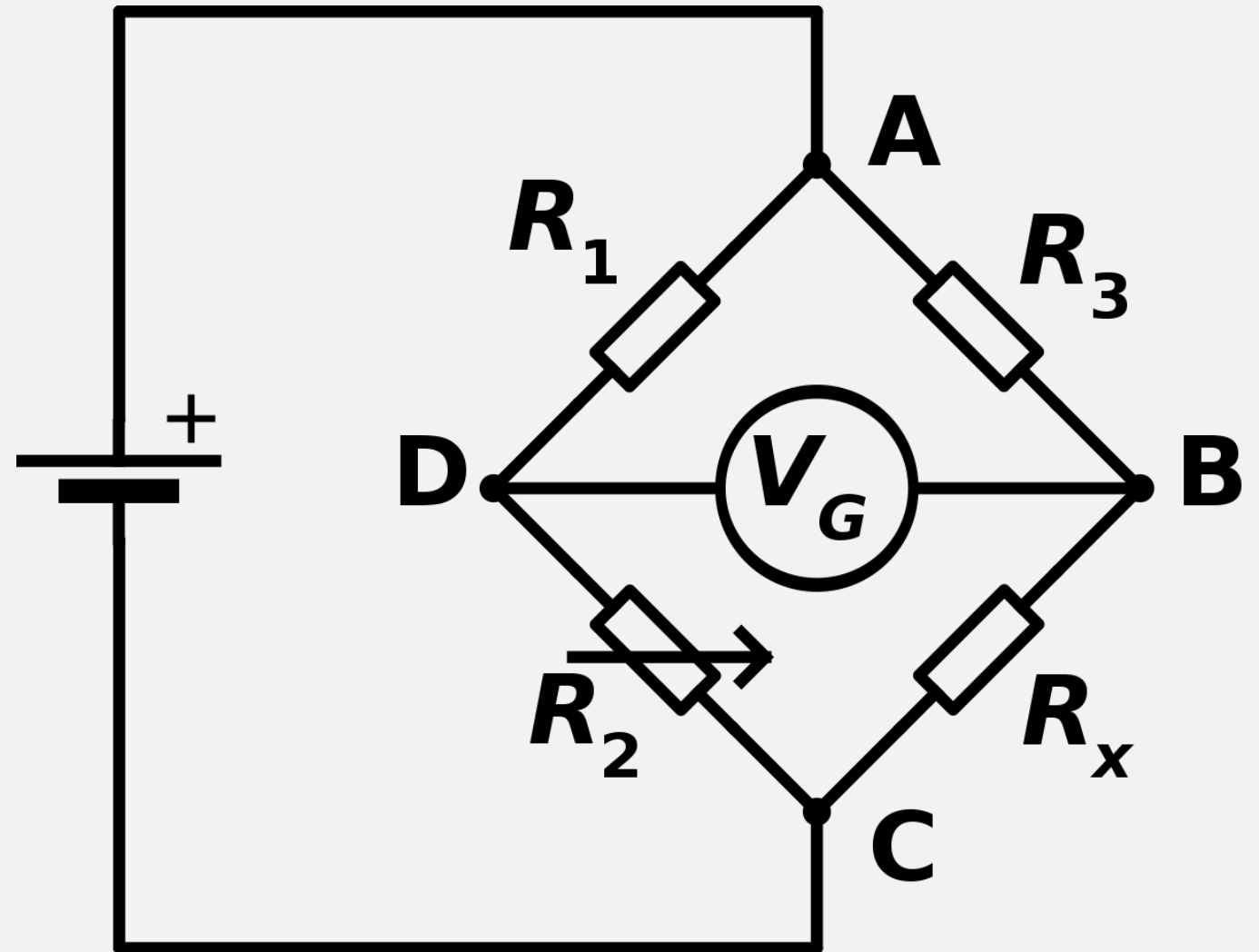
Advantages:

- Fast, easy data
- All components on-hand



Data Collection

- Wheatstone Bridge and Rosette Gauges
- Strain Gauges will be attached to the chain anchors
- Voltage data collected with LabView and a National Instruments DAQ
- Collected data can be analyzed with MATLAB
- Will need to take spring rate of the leaf chain into consideration when performing analysis



Experiment Design

- Items to run over:
 - 2x4
 - Pallet Board
 - Extension cord
 - Air hose
 - Gravel lot
 - Large pothole
- Loads to test:
 - Unloaded
 - The forklift we have access to has a rotator attachment
 - 1000 pound load
 - 2000 pound load
 - 3000 pound load

Data Collection: Current progress



Materials have arrived



Developing LabView
Data Acquisition
Code



Forward Looking:
Data Collection and
Analysis

Full Scale Prototype

- Receiving carriage and forks from HYG
- Installing prototype
- Return to HYG to be installed on Forklift
- Test at HYG location with or without us depending on Covid-19 development

Potential Risks

- Hydraulic power requirements may take away the ability to add other auxiliary functions
- Wear on the mast J-Channel can compromise the integrity over time
- Increased Maintenance costs
- Adding rigidity to the system may cause unforeseen consequences
 - Less give in the system causing increased wear on components



Project Schedule

		Project: Hyster Yale Carriage Bounce Control System																																														
		Last Updated: 2/24/20																																														
		2020														2021																																
		Month	Sept				Oct				Nov				Dec				Jan				Feb				Mar				Apr				May													
Task Description	Duration	Assigned	9/4	9/13	9/20	9/27	10/4	10/11	10/18	10/25	11/1	11/8	11/15	11/22	11/29	12/6	12/13	12/20	12/27	1/3	1/10	1/17	1/24	1/31	2/7	2/14	2/21	2/28	3/7	3/14	3/21	3/28	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30							
Finalization of Idea																																																
Design Validation Plan								X																																								
Focused Research																																																
Value Proposition										X																																						
Basic Mockups																																																
Wikipage											X																																					
Concept Design Review												X																																				
Team Member Citizenship													X																																			
Measurement and Data Aquisition																																																
CAD Modeling and FEA Simulation																																																
Strain Gauge Measurement																																																
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Initial Prototype																																																
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Team Member Citizenship																																																
Portfolio																																																
Wikipage																																																
Final Prototype																																																
Validation and testing (At Hyster)																																																
Complete Prototype Build																																																
UI Design EXPO																																																
Booth Display																																																
Technical Presentation																																																
Final Reports and Drawings to client																																																



Questions?