NFPA Fluid Power VEHICLE Challenge

NFPA Education and Technology Foundation

Final Presentation
Purdue University Northwest
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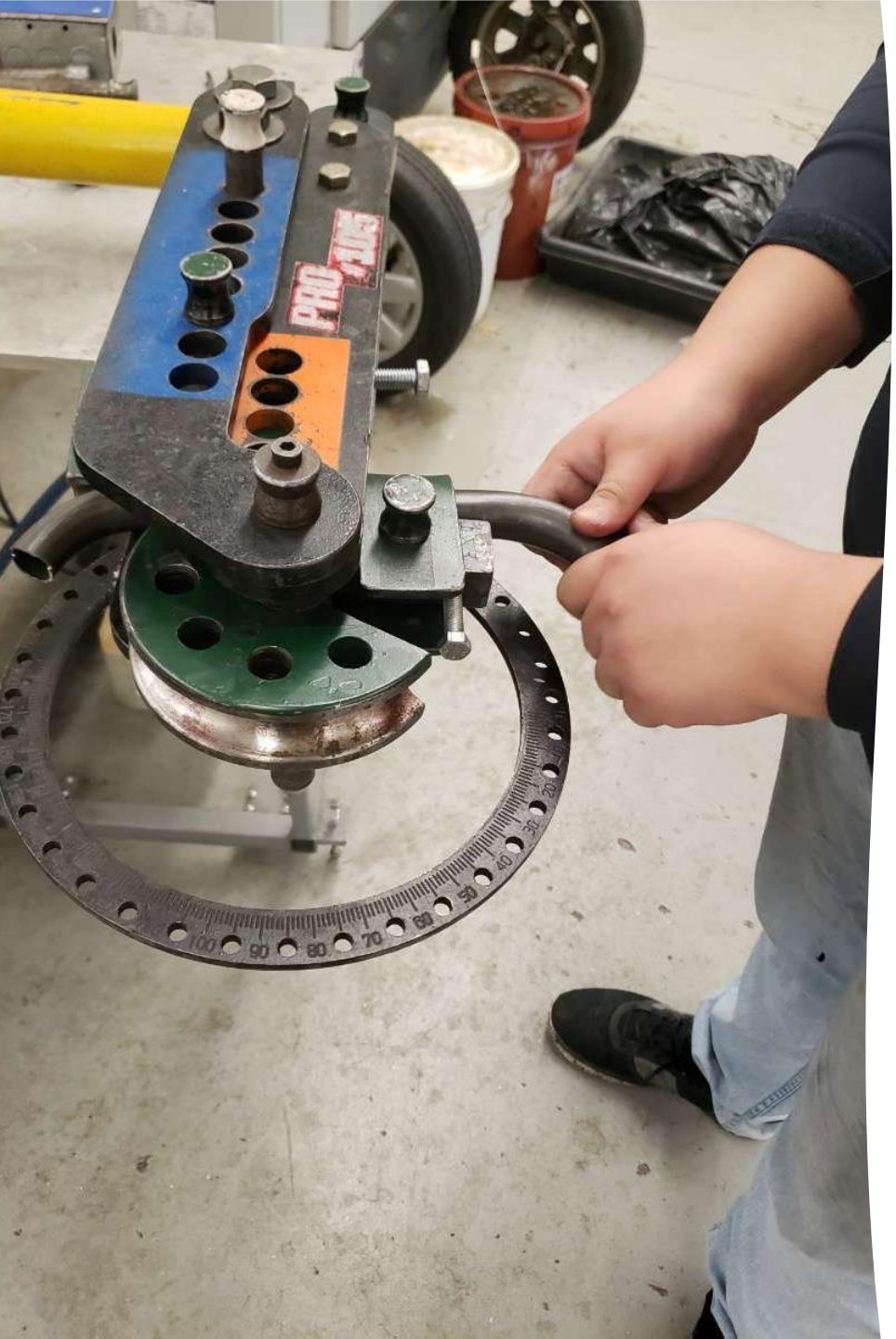
PURDUE UNIVERSITY NORTHWEST

DATE: December 9th, 2022

The 2022 PNW Fluid Power Vehicle Team!

- From left to right: Alireza Alavizadeh, Enoc Gutierrez, Samuel Torres, Adam Hayman, Diego Jimenez



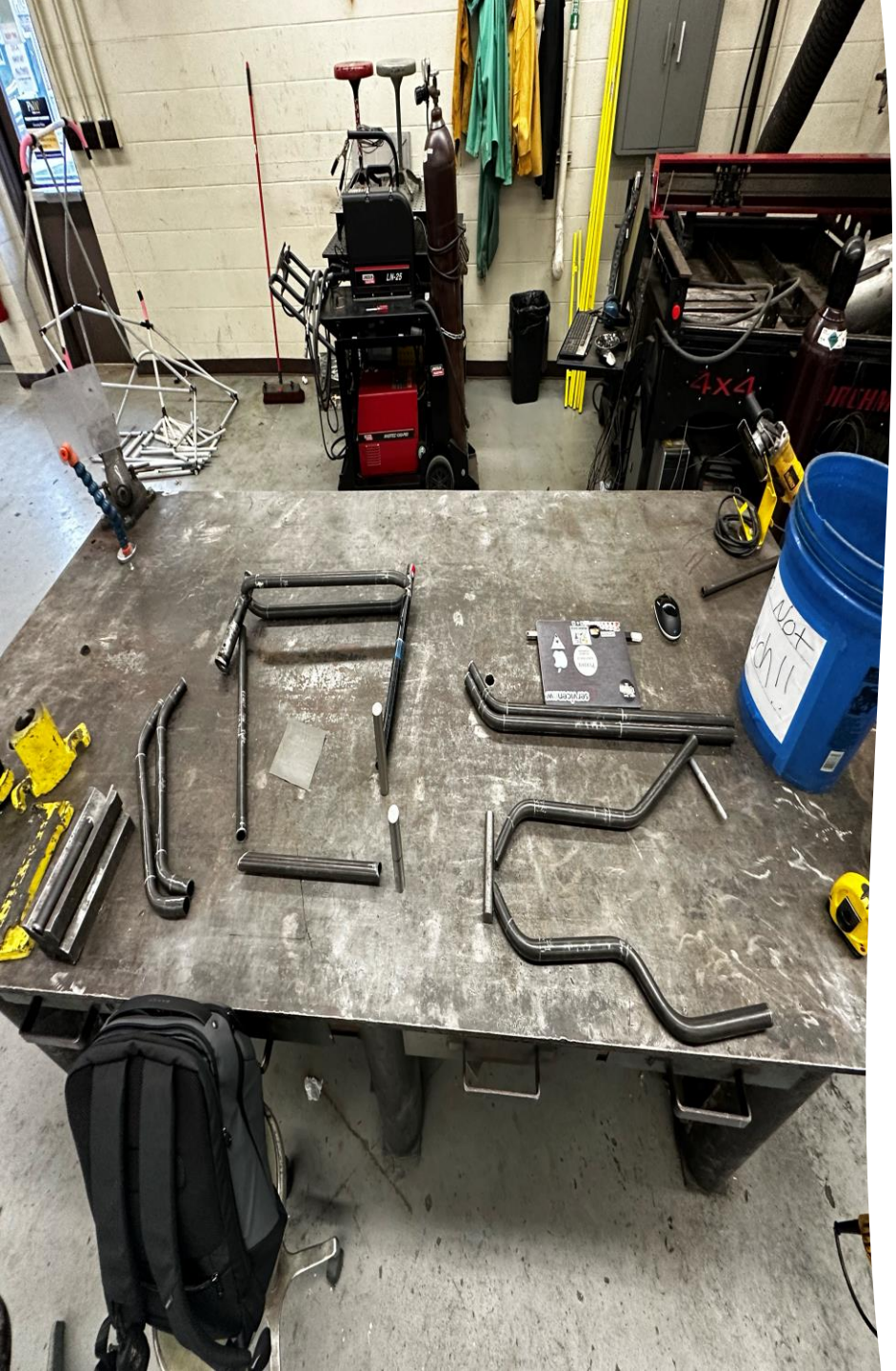
NFPA Fluid Power Vehicle Challenge

Project Specifications

- Compete in 4 Race
  - Sprint – Distance 600ft.
  - Regenerative Breaking – Restore power in accumulator.
  - Endurance – Farthest distance in a time period.
  - Efficiency – Hydraulic system.
- Max bike weight <= 210lbs.
- 3000 psi max.
- Bike Design Safety for Exposed Hazards.

Design Objectives

- Hydraulic driven vehicle powered by pedaling.
- Maximum pressure is 3000psi.
- Design our own Hydraulic Schematic.
- PLC to control pneumatic and hydraulic systems.
- Design a manual transmission gear box.
- Design a spoke-less front wheel.
- Design a Reservoir.



Project Deliverables

The design of this vehicle will require a submission of the following:

- An entry video of a working vehicle.
- Midway Review: Components list of everything purchased before build phase.
- Appealing to the eye with RGB lighting.
- Added training wheels for balancing.
- Detailed analysis of frame and calculations.
- Race vehicle in 4 races: Sprint, Regenerative, Endurance, and Efficiency.

NFPA Fluid Power Vehicle Challenge

Proof of Working Vehicle

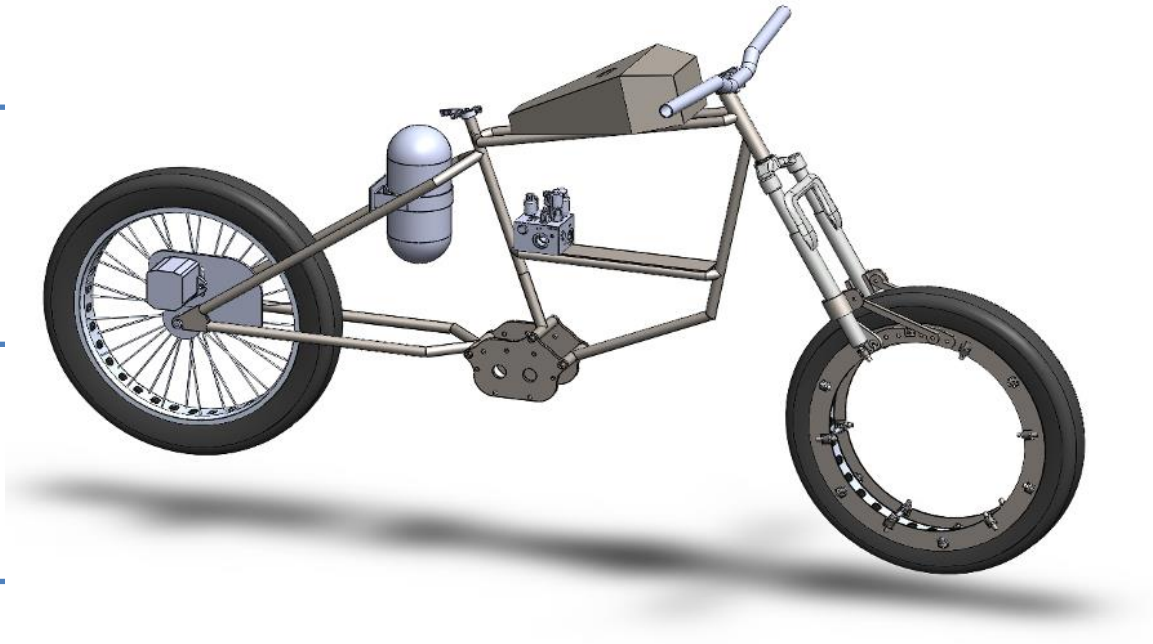
Fabrication

Welded Construction

Material: Chromoly 4130 round tubing

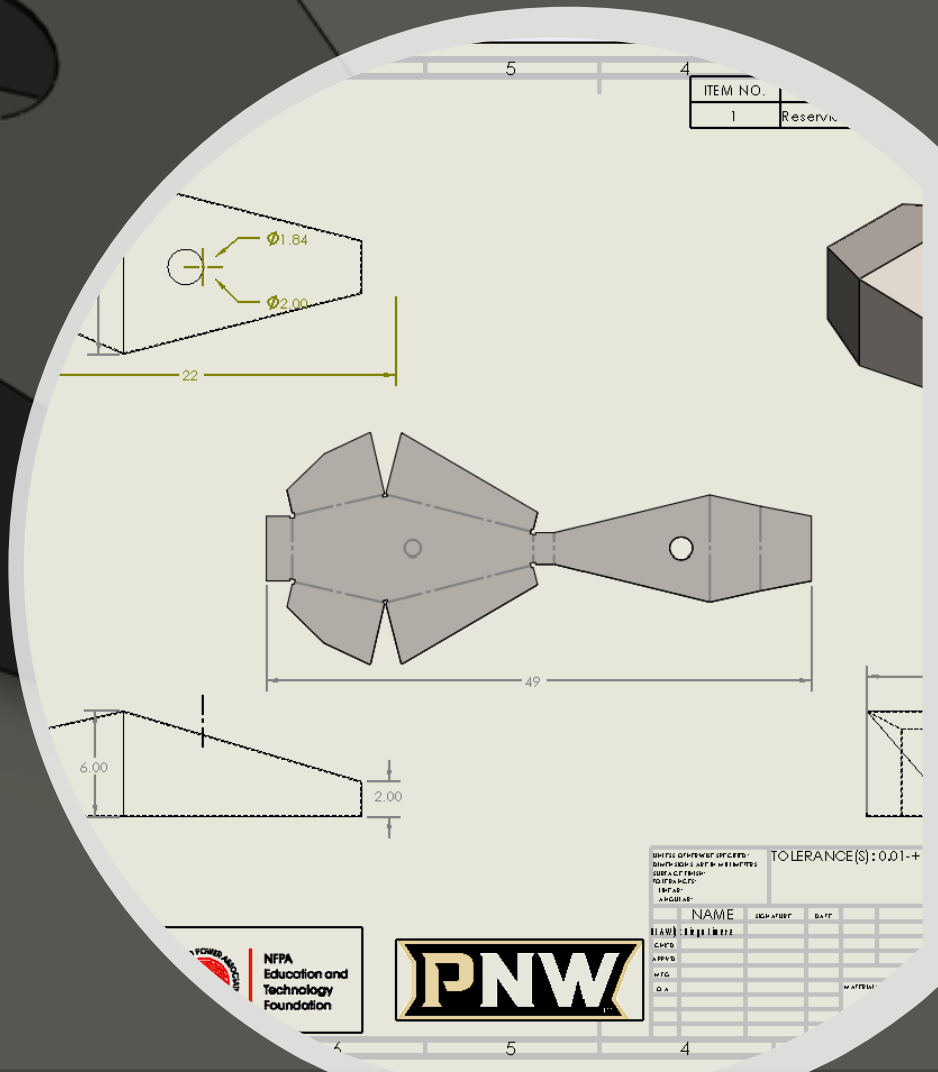
Pedals on gear box

Aiming for a Hybrid style: Naked/Classic Motorcycles

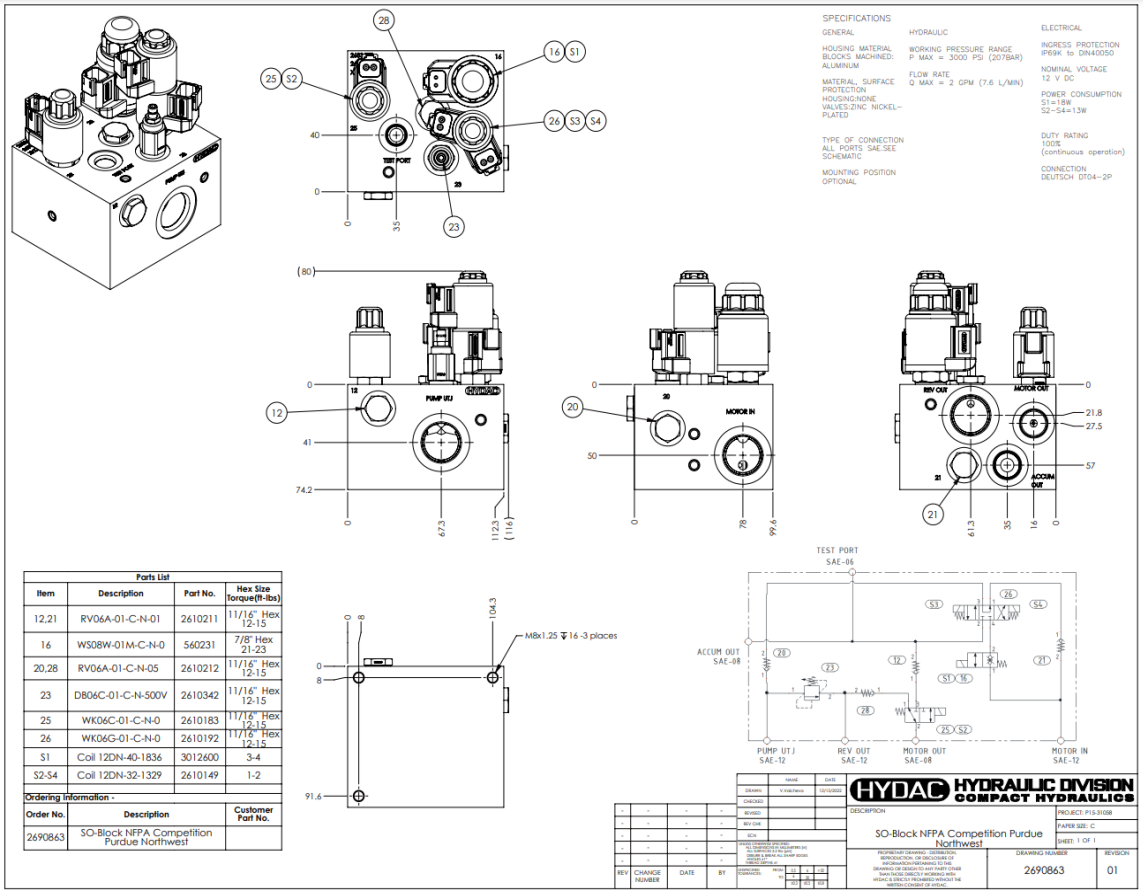


Reservoir

- Ergonomic design
- 3 gallons of oil
- A36 steel sheet metal
- Thickness of 0.0747"



Manifold Design

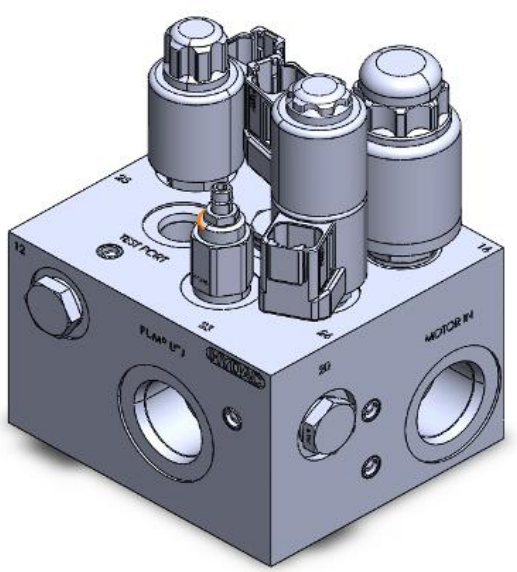


Parts List

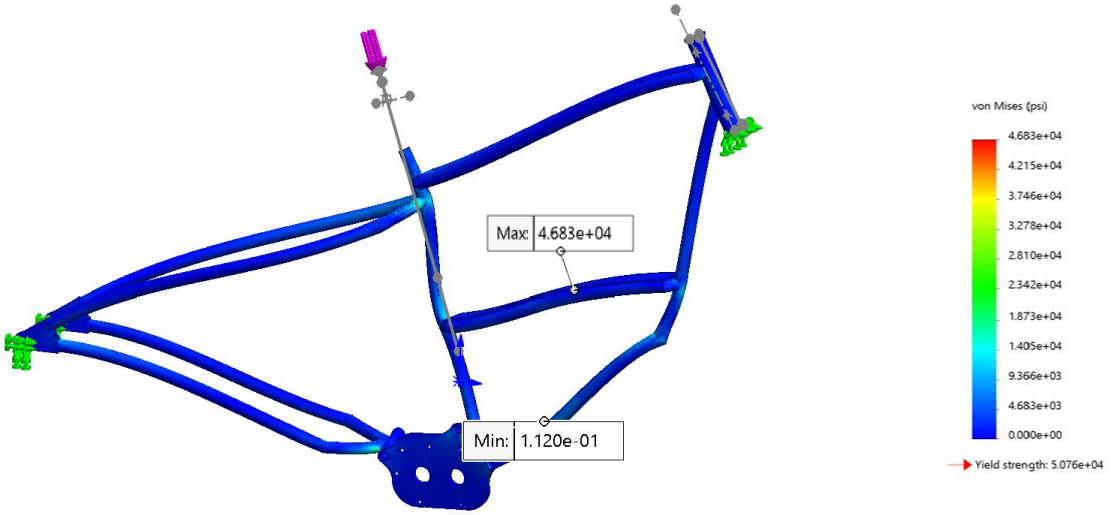
Item	Description	Part No.	Hex Size Torque(ft-lbs)
12,21	RV06A-01-C-N-01	2610211	11/16" Hex 12-15
16	WS08W-01M-C-N-0	560231	7/8" Hex 21-23
20,28	RV06A-01-C-N-05	2610212	11/16" Hex 12-15
23	DB06C-01-C-N-500V	2610342	11/16" Hex 12-15
25	WK06C-01-C-N-0	2610183	11/16" Hex 12-15
26	WK06G-01-C-N-0	2610192	11/16" Hex 12-15
S1	Coil 12DN-40-1836	3012600	3-4
S2-S4	Coil 12DN-32-1329	2610149	1-2

Ordering Information -

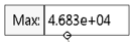
Order No.	Description	Customer Part No.
2690863	SO-Block NFPA Competition Purdue Northwest	



Frame FEA



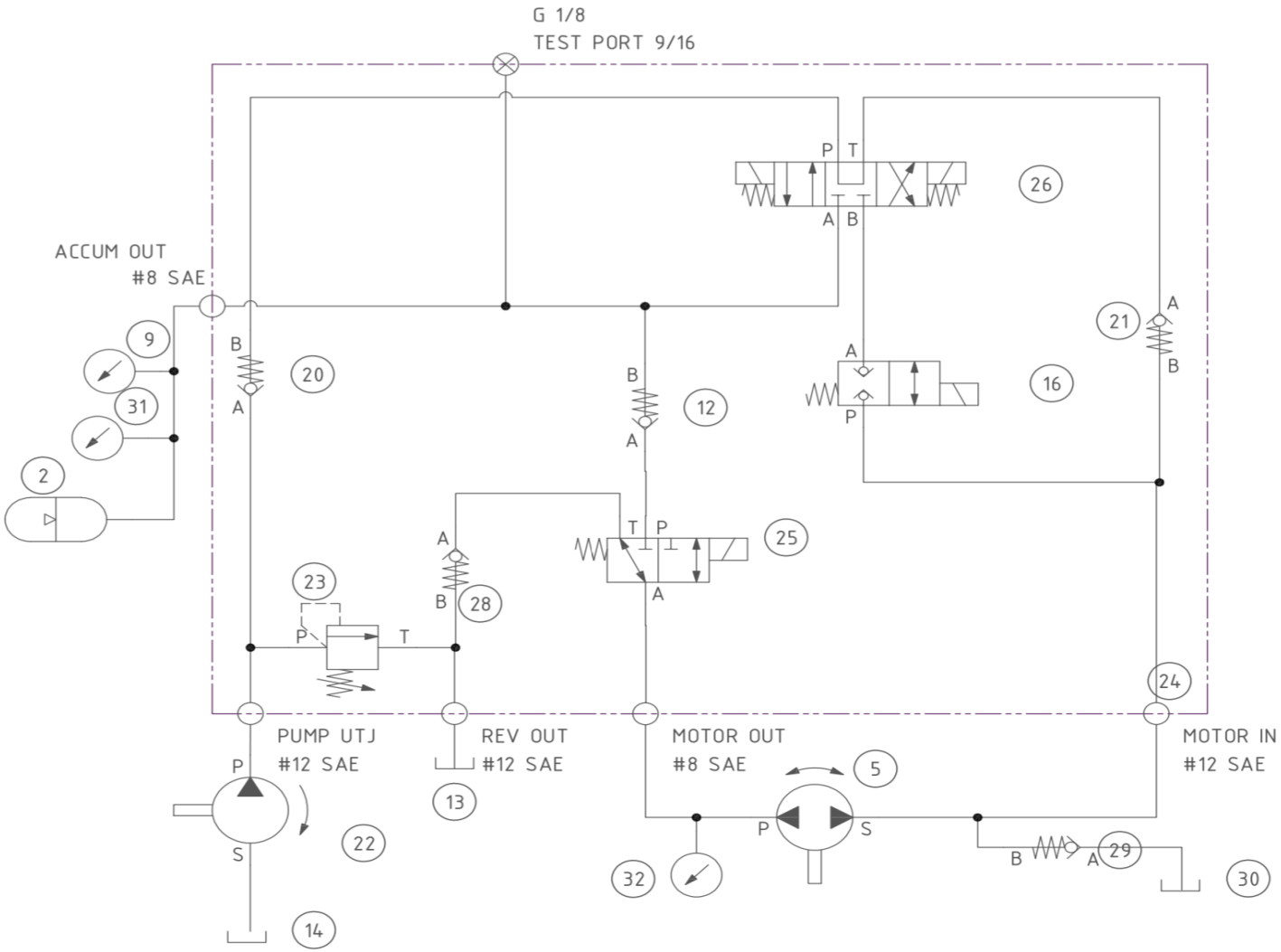
Stress = 268.8 psi



Frame FEA

FOS = 3.2

Hydraulics Circuit Design



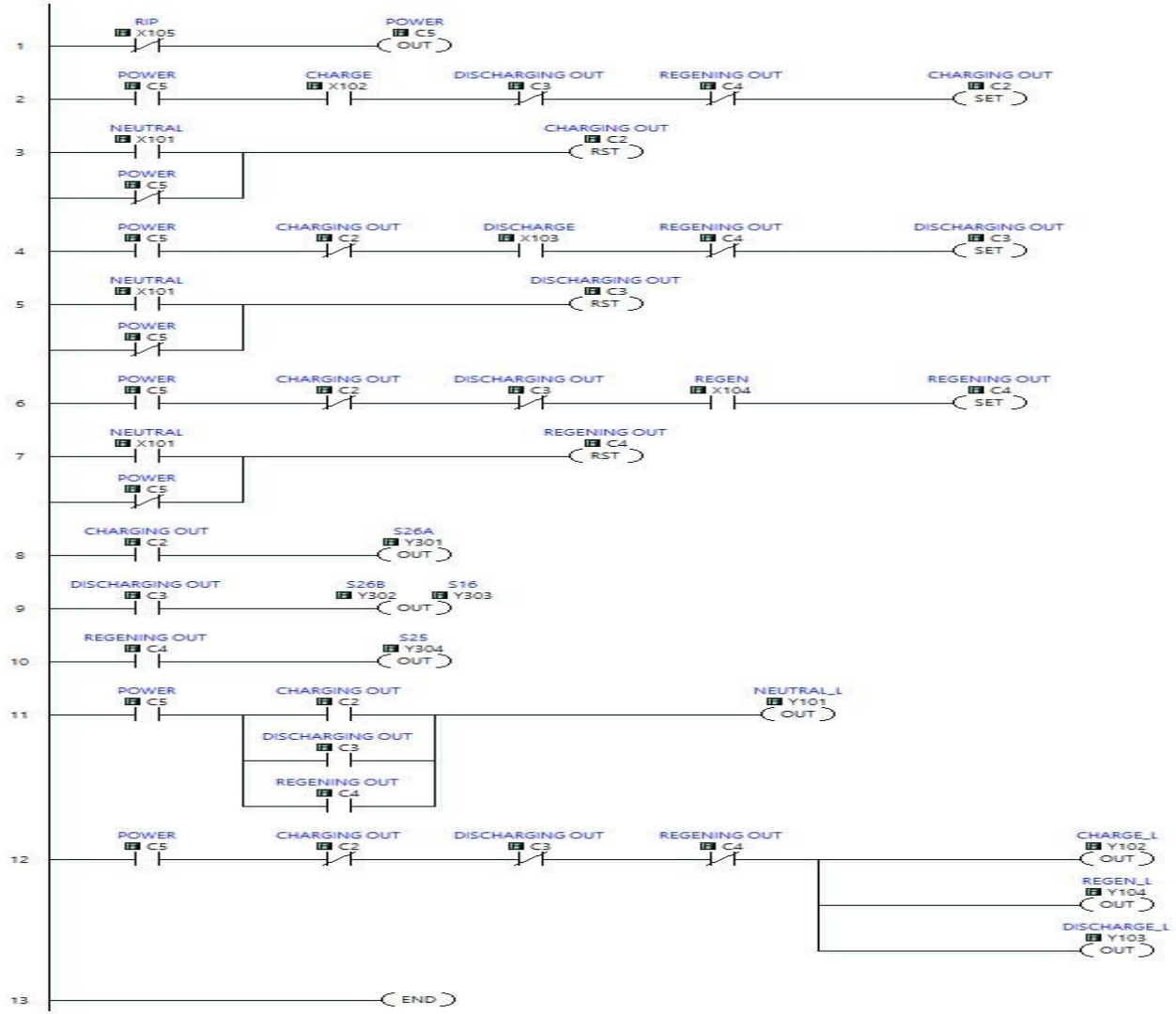
Selection of Hardware

DESCRIPTION	MODEL CODE	PART NUMBER
Size -6 Solenoid Coil, 32mm, 12V Deutsch	Coil 12DN-32-1329 QS	2610149
Pressure Relief, Direct Acting, Poppet Type 2500 p	DB06C-01-C-N-500V QS	2610342
Check Valve, Ball type	RV06A-01-C-N-01 QS	2610211
Check Valve, Ball type	RV06A-01-C-N-05 QS	2610212
Directional 3W/2P Direct Acting, Spool Type	WK06C-01-C-N-0 QS	2610183
Directional 4W/3P Direct Acting, Spool Type	WK06G-01-C-N-0 QS	2610192 OR THE WK10G-01
Poppet Type, Bi-directional, Normally Closed, Direct Acting	WS08W-01	
Hydraulic Test point	1620 (9/16-18 UNF) MC/NBR	6003737

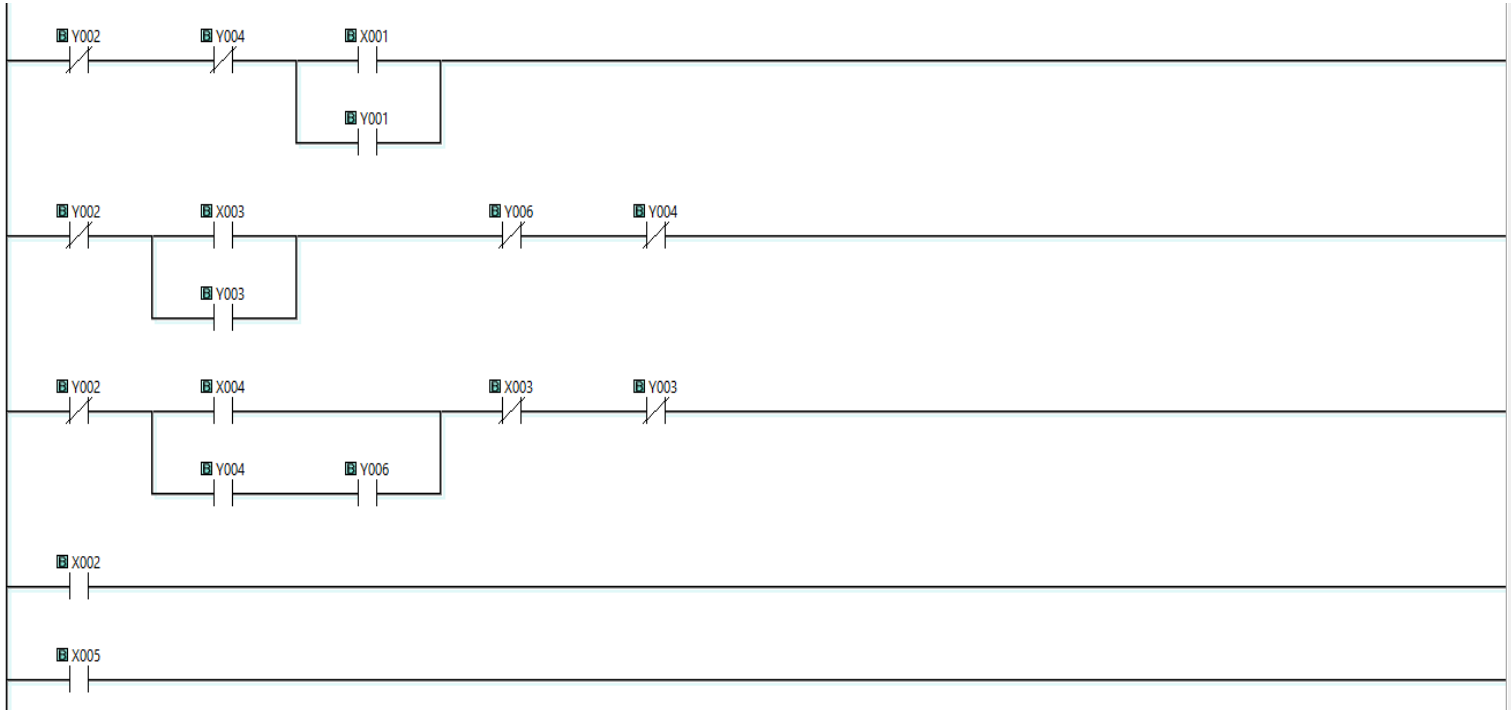
ITEM ID	PORT
MOTOR IN, REV OUT, PUMP UTJ	SAE-12
MOTOR OUT, ACCUM OUT	SAE-08

PLC Ladder Logic

rst click plc code.

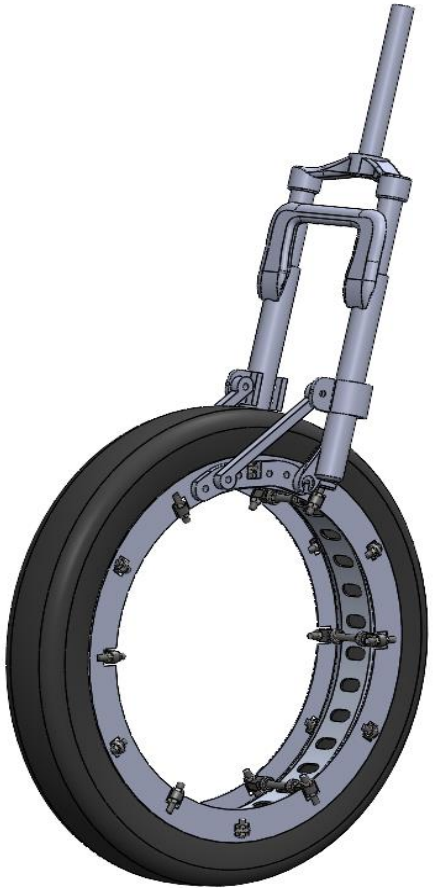


Using the Click Program



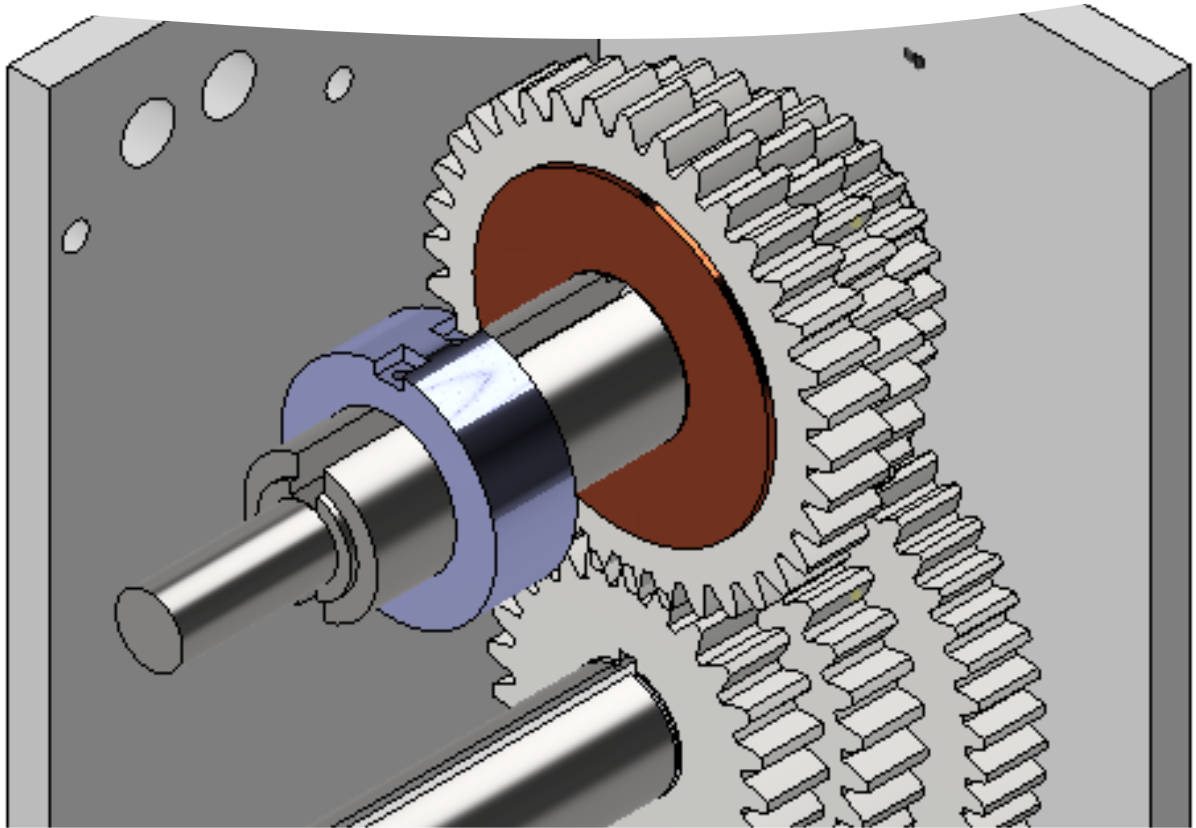
Front Wheel Design

- Spokeless wheel
- 2 plates and Bearings
- Hydraulic Bicycle fork
- Aluminum 6061
- A36 steel frame
- 4-inch-thick wheel

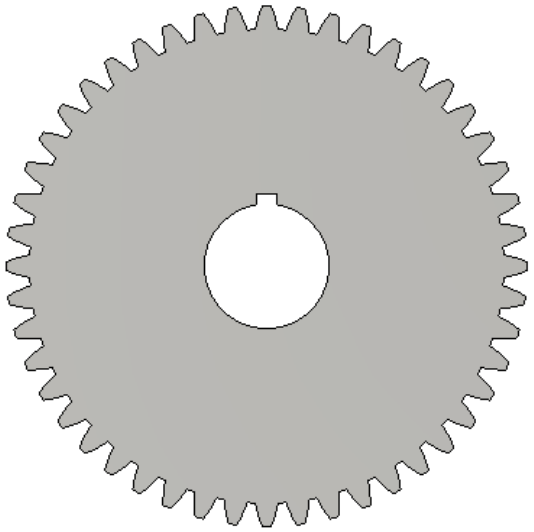


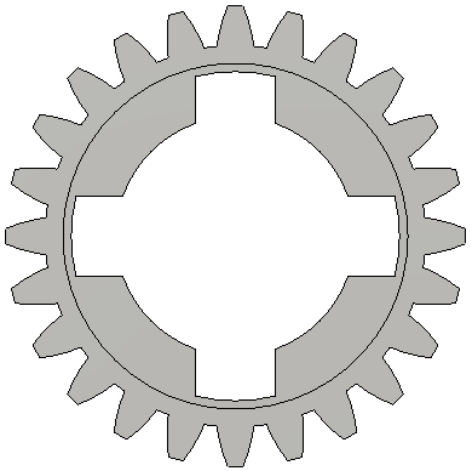
Gearbox Design

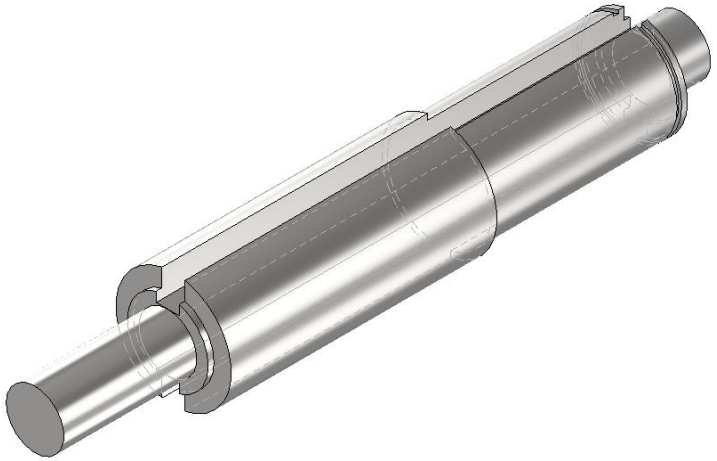
- 3 Speed manual transmission
- 1st Gear - .66:1 Ratio
- 2nd Gear – 1:1 Ratio
- 3rd Gear – 2:1 Ratio



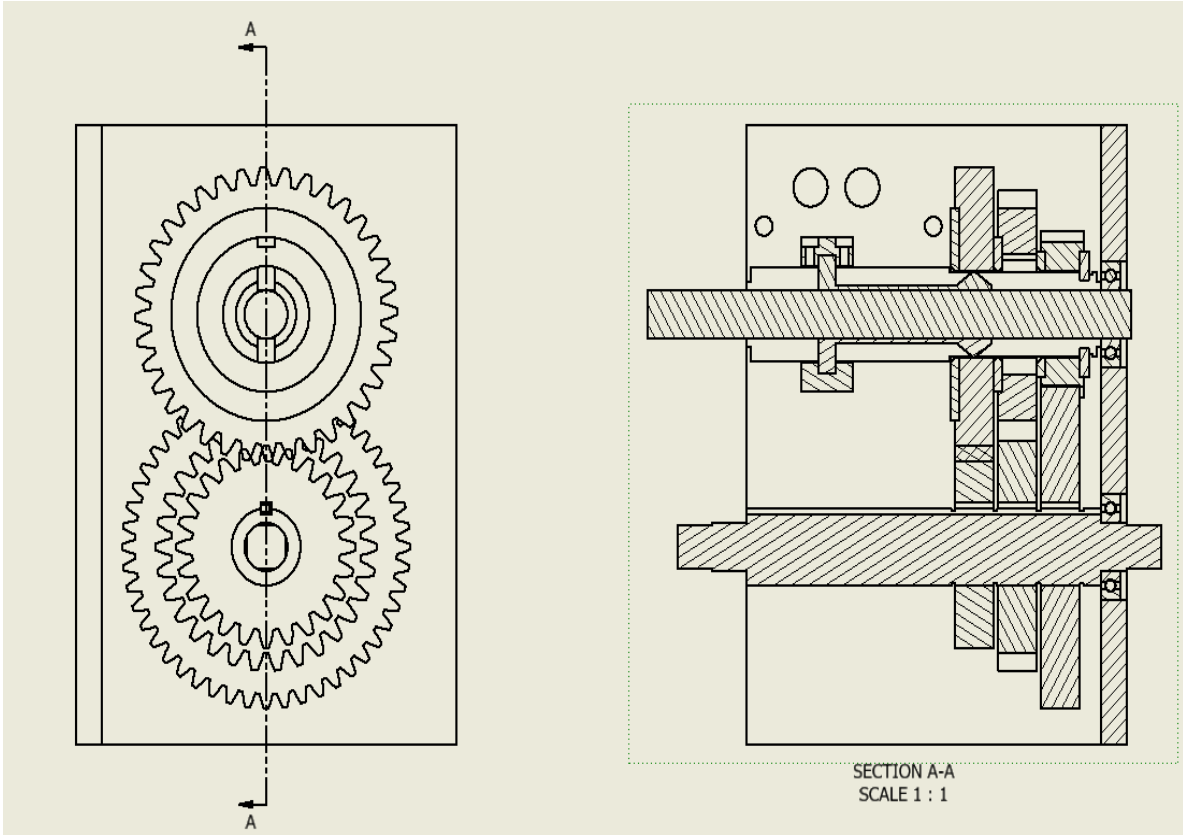
Gearbox Main Components







Gearbox Cross Section



Safety assessment

- Exposed gears on right side of pedals
  - Initial risk level of 16
- Boxing with aluminum plates
  - Acceptable Initial risk level of 2

	Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Highly possible 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Possible 3	3	4	9	12	15
Unlikely 2	2	4	4	8	10
Rare 1	1	2	3	4	5

Figure 14: Risk Level Matrix Chart

Gear and Hydraulic Calculations

3Speed Transmission Calculations

Formulas	1st Gear	
V.R. = n_input /n_output = N_output/ N_input	Gear Ratio	1.5:1
CD= (PD_1 + PD_2)/2	# Teeth gear 1	24
	# Teeth gear 2	36
	Input Speed (rpm)	90
	Output Speed (rpm)	60.00
	2nd Gear	
	Gear Ratio	1:1 _
	# Teeth gear 3	30
	# Teeth gear 4	30
	Input Speed (rpm)	90
	Output Speed (rpm)	90
	3rd Gear	
	Gear Ratio	2:1 _
	# Teeth gear 5	48
	# Teeth gear 6	24
	Input Speed (rpm)	90
	Output Speed (rpm)	180

Hydraulic Pump Calculations

Formulas	1st Gear	
Q= V_D * n	Volumetric Displacement (in3 / rev)	0.69
Q_a = n_v * Q_T	Speed (rpm)	60.00
	Flow Rate (in3 / rev)	41.40
	Actual (in3 / rev)	37.26
	Efficiency	90%
	2nd Gear	
	Volumetric Displacement (in3 / rev)	0.69
	Speed (rpm)	90
	Flow Rate (in3 / rev)	62.1
	Actual (in3 / rev)	55.89
	Efficiency	90%
	3rd Gear	
	Volumetric Displacement (in3 / rev)	0.69
	Speed (rpm)	180
	Flow Rate (in3 / rev)	124.2
	Actual (in3 / rev)	111.78
	Efficiency	90%

Theoretical and Speed Calculations

Hydraulic motor Calculations			Speed of Vehicle Calculations		
Formulas	1st Gear		Formulas	1st Gear	
Q= V_D * n	Volumetric Displacement (in3 / rev)	0.69	V_bike = Radius * n_ motor	Radius (in)	13
Q_T = n_v *Q_A	Speed (rpm)	48.60		Motor Speed (rpm)	48.60
	Theoretical (in3 / min)	33.53		Bike Speed (MPH)	3.75
	Actual (in3 / min)	37.26		2nd Gear	
	Efficiency	90%		Radius (in)	13
	2nd Gear			Motor Speed (rpm)	72.9
	Volumetric Displacement (in3 / rev)	0.69		Bike Speed (MPH)	5.62
	Speed (rpm)	72.9		3rd Gear	
	Theoretical (in3 / min)	50.301		Radius (in)	13
	Actual (in3 / min)	55.89		Motor Speed (rpm)	145.8
	Efficiency	90%		Bike Speed (MPH)	11.25
	3rd Gear				
	Volumetric Displacement (in3 / rev)	0.69			
	Speed (rpm)	145.8			
	Theoretical (in3 / min)	100.602			
	Actual (in3 / min)	111.78			
	Efficiency	90%			

Gantt Chart

Fluid Power Club Hydraulic Vehicle Challenge Build Timeline

Company name

Project lead

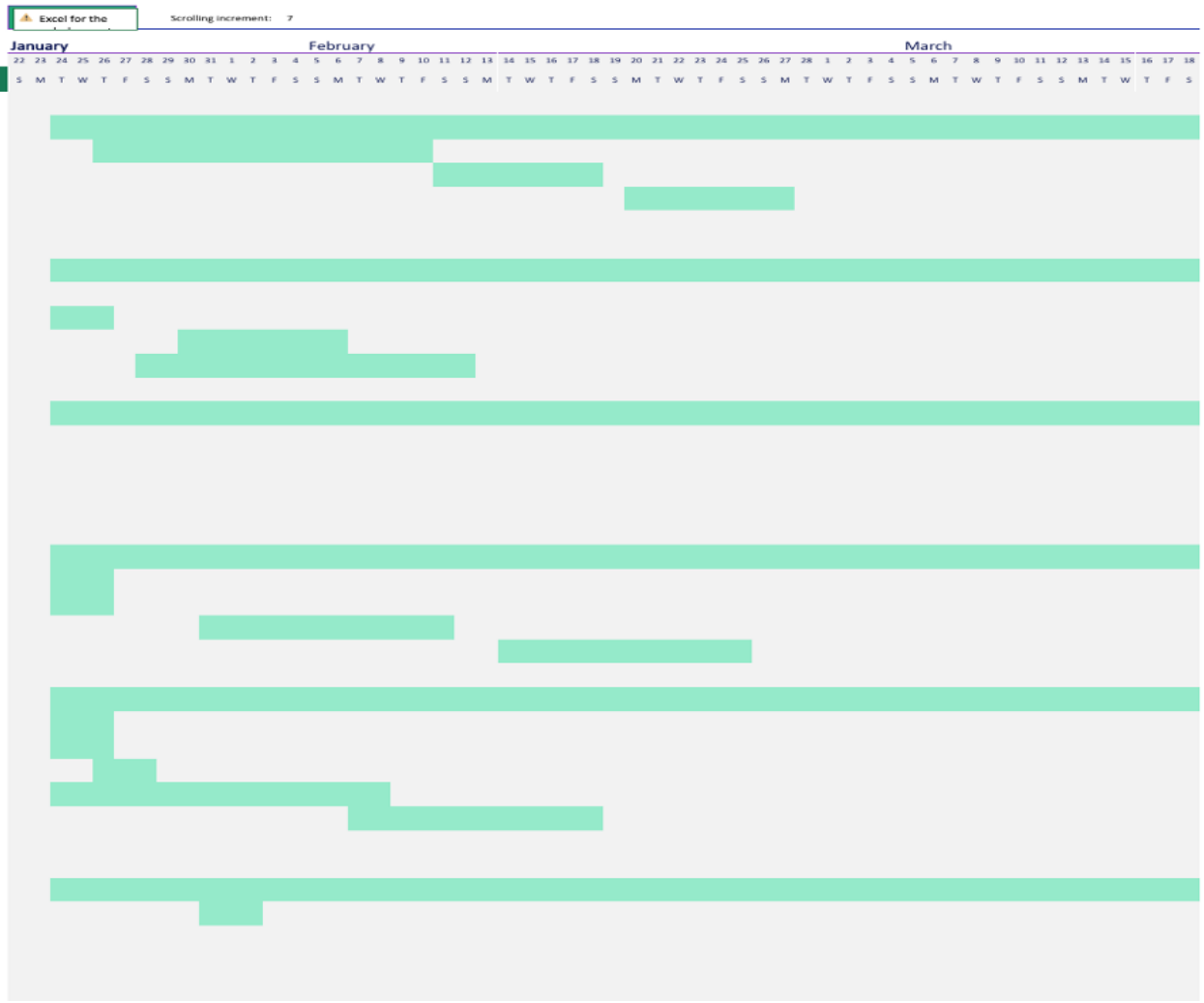
Project start date: 1/15/2023

Milestone marker: 3

Excel for the

Scrolling increment: 7

Milestone description	Assigned to	Progress	Start	Days
CHASSIS				
TOTAL COMPETION	DIEGO J	100%	1/23/2023	69
CUT TUBES	DIEGO J	100%	1/25/2023	18
WELD TUBES	DIEGO J	100%	2/10/2023	10
ASSEMBLE COMPONENTS	DIEGO J	100%	2/19/2023	10
FINISH SLDR CHASSIS	DIEGO J	100%	1/18/2023	5
GEAR BOX				
TOTAL COMPLETION	SAMUEL T	50%	1/23/2023	69
SEND GEAR DESIGN	SAMUEL T	100%	5/10/2023	27
GEARBOX CASE	SAMUEL T	0%	1/23/2023	5
SHIFTER DESGN	SAMUEL T	0%	1/29/2023	10
SHAFT/ CASE MANF'C	SAMUEL T	100%	1/27/2023	18
PNEUMATICS				
TOTAL COMPLETION	SAMUEL T	35%	1/23/2023	69
CREATE PNUEMATIC SCHEM	SAMUEL T	100%	5/14/2023	14
BUY PNEMATIC PARTS	SAMUEL T	85%	5/30/2023	6
ASSEMBLE PNUEMATICS	SAMUEL T	0%	6/12/2023	3
SPOKELESS WHEEL				
TOTAL COMPLETION	ENOC/DIEGO	95%	1/23/2023	69
FINISH SLDR DESIGN	DIEGO J	100%	1/23/2023	5
BUY PARTS	ENOC G	100%	1/23/2023	5
CREATE JOINTS/CUT SHEET	DIEGO J	100%	1/30/2023	14
ASSEMBLE FRONT WHEEL	ENOC G	90%	2/13/2023	14
PLC/ ELECTRICAL				
TOTAL COMPLETION	ENOC/SAM	100%	1/23/2023	69
CREATE LADDER LOGIC	ENOC G	100%	1/23/2023	5
BUY PLC	ENOC G	100%	1/23/2023	5
BUY SENSORS	SAMUEL T	100%	1/25/2023	5
ELECTRICAL COMPONETS	SAMUEL T/ADAM H	95%	1/23/2023	18
ASSEMBLE COMPONENTS	ADAM H	85%	2/6/2023	14
RESERVOIR				
TOTAL COMPLETION	DIEGO J	100%	1/23/2023	69
RESERVOIR HOSE CONNECTIONS	DIEGO J	100%	1/30/2023	5
RESERVOIR BUILD	ENOC G	100%		
RESERVOIR SLDR DRWG	DIEGO J	100%		
RESERVOIR CUT AND WELD	DIEGO J	100%	2/17/2023	



PARTS LIST

No.	NAME	COMPANY	PRICE	QUANTITY	TOTAL	FINAL TOTAL
1	26X4 Rim Fat Tire Bicylce	EERONS	44.99	1	$44.99	$2,643.85
2	26x4 Fat tire Suspension Fork	BUCKLOS	104.99	1	$104.99	
3	Alex Blizzerk 19x197mm Fat tire Bike Rear Wheel	Bikesmiths	289.75	1	$289.75	
4	Equalizer Bike Stem	Funn	74.67	1	$74.67	
5	MTB Riser Handlebar	FIFTY-FIFTY	39.99	1	$39.99	
6	ST6246 Deutsch 2 pin connector	JReady	39.99	1	$39.99	
7	Miniature Ball Bearing 3/8 ID	Donepart	12.99	1	$12.99	
8	Threaded Rod	Hillman Group	7.99	1	$7.99	
9	Nylon Insert Hex Lock Nuts	SG TZH	20.99	1	$20.99	
10	Zig Zag 26x4 Street Bike Tires	Vee Tire Co.	199.98	1	$199.98	
11	MTB Crank Arm Set	Ganopper	42.99	1	$42.99	
12	Gorrilla Duct Tape	Gorrilla	15.69	1	$15.69	
13	1x.065 4130 Round Tube, Chromoly per foot	AED Metal Products	4.66	90	$419.40	
14	14 GA x 48" x 96" sheet	AAA Supply	98.12	1	$98.12	
15	11 GA x 48" x 96" sheet	AAA Supply	137.15	1	$137.15	
16	16 GA x 48" x 96" sheet	AAA Supply	78.4	1	$78.40	
17	Pressure Transmitter 0 to 3000psi	GRAINGER	206	1	$206.00	
18	1.25" Alloy steelRound Bar 4130 C.F.	Online Metals	76.99	1	$76.99	
19	External retaining ring 1"	McMaster	11.14	1	$11.14	
20	External retaining ring 1-1/8"	McMaster	6.99	1	$6.99	
21	Crimping Tool	Haisstronica	26.99	1	$26.99	
22	DIN Rail	T&G	16.99	1	$16.99	
23	Alloy steel cup pint set screw 12-24 3/16	McMaster	6.03	2	$12.06	
24	Alloy steel cup pint set screw 12-24 1/4	McMaster	5.97	1	$5.97	
25	240 pcs Hexbols and nuts kit	Hakkin	25.99	1	$25.99	
26	74 pcs 3/8-16 hex bolts and nuts kit	Hakkin	20.54	1	$20.54	
27	3/8 inch Stainless Flat Washers	Lupanter	8.99	1	$8.99	
28	Bicyle Seat Post 26.8mm	Teyssor	16.99	2	$33.98	
29	1 1/8 inch Headset Spacer	Ganopper	8.99	1	$8.99	
30	SDG Lock on Grips 130mm	ODI	27.95	1	$27.95	
31	Mountain Bike Pedals 9/16	Shanmashi	25.99	1	$25.99	
32	Headset Mounting Device	Park Tool	25.95	1	$25.95	
33	M8 x 1.0 Metric tap and Die	Aceteeel	12.99	1	$12.99	
34	6 sets 3/8 16x2-1/2 inch hex botls	Fullerkreg	12.99	4	$51.96	
35	4 sets 3/8-16x4 inch hex screw	Fullerkreg	10.99	4	$43.96	
36	3/8-16x7 inch ehx bolts	Mellewell	12.99	4	$51.96	
37	8mm bike hex Crank arm Fixing bolt	Vanice	6.9	4	$27.60	
38	Bicyle Headset 4456st	VGEBY1	22.29	1	$22.29	
39	1-1/8 Heavy duty Headset top cap bearings	YOU+1	9.1	1	$9.10	
40	83Pcs Universal Bike Cable Housing	Keadic	22.98	1	$22.98	
41	Bicyle Cable Adjusters	Dioche Store	7.89	5	$39.45	
42	Mountain Bike Disc Brake Kit	Bucklos	34.99	1	$34.99	
43	Complete Bike Brake Set	Boao	20.99	1	$20.99	
44	926 III 60W Digital Display Soldering Iron	YIHUA	42.9	1	$42.90	
45	Solder Wick Braind with flux 10ft	Lesnow	7.99	1	$7.99	
46	Rust-Oleum Black Paint	Rust-Oleum	37.14	1	$37.14	
47	R6 2RS Bearings 3/8 ID x 7/8 OD x 9/32	Donepart	11.99	4	$47.96	
48	25 pcs Drawer Organizer set	Lifewit	17.39	1	$17.39	
49	Aluminum quick Rekease Seat Post Clamp 31.8mm	DEERU	8.99	1	$8.99	
50	Metal Gear 10 pitch 20 teeth	McMaster	63.22	1	$63.22	
51	Fat Bike Hi Tensile Fork	Messingshlager	50.93	1	$50.93	
52	McMastercar Bar Stock for mounts	McMaster	165.2	1	$165.20	
53					$0.00	
54					$0.00	
55					$0.00	
56					$0.00	
57					$0.00	
58					$0.00	
59					$0.00	

No.	NAME	COMPANY	PRICE	QUANTITY	TOTAL	FINAL TOTAL
1	Gear Pump, 0.659 CID, Keyed Shaft .625", CW rotation	DANFOSS	$255.00	2	$510.00	$5,510.37
2	Gear Pump, 0.659 CID, 9 tooth spline, CCW rotation	DANFOSS	$255.00	1	$255.00	
3	Size -6 Solenoid Coil, 32mm, 12V Deutsch	HYDAC	$19.26	7	$134.82	
4	Pressure Relief, Direct Acting, Poppet Type	HYDAC	$42.38	1	$42.38	
5	Check Valve, Ball type	HYDAC	$15.18	3	$45.54	
6	Check Valve, Ball type	HYDAC	$15.18	3	$45.54	
7	Directional 3W/2P Direct Acting, Spool Type	HYDAC	$47.65	1	$47.65	
8	Directional 4W/3P Direct Acting, Spool Type	HYDAC	$77.45	1	$77.45	
9	**Hydraulic Test point**	HYDAC	$21.99	1	$21.99	
10	**Accumulator**	SunSource	$999.00	1	$999.00	
11	**WS08W-01**	HYDAC	$50.00	1	$50.00	
12	C0-01AC	Automation Direct	$54.00	1	$54.00	
13	C0-12DD2E-1-D	Automation Direct	$246.00	1	$246.00	
14	C0-16CDD2	Automation Direct	$80.00	2	$160.00	
15	C0-4TRS-10	Automation Direct	$67.00	3	$201.00	
16	C0-4TRS	Automation Direct	$60.00	2	$120.00	
17	Gears from Gear Headquarters	Gear Headquarters	$250.00	10	$2,500.00	
18					$0.00	
19					$0.00	
20					$0.00	
21					$0.00	
22					$0.00	
23					$0.00	
24					$0.00	
25					$0.00	
26					$0.00	
27					$0.00	
28					$0.00	
29					$0.00	
30					$0.00	
31					$0.00	

NFPA Fluid Power Vehicle Challenge

Parts List

Conclusion

After testing:

- Bike weight = 197.4lbs w/o oil
  = 205lbs w/ oil
- The first run had oil leaks on the sensors
- More weight needed on the left side.
- The gear ratio had to be increased.
  - More torque to the motor means less speed

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