

MuthAir 150 - A Pneumatic Powered Bike

UC Fluid Power Club

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Abstract

This senior design project covers creating a bike using air as a compressible fluid. The bike will be belt-driven and use a double-acting piston. This document reviews the theoretical calculations made on the bike before its construction, the bill of materials used on the bike, the construction of the bike, and the actual outcome, oversights, and corrections made and corrections issued to the next generations.

Introduction

A pneumatic bike is a means of transportation that is powered using a fluid system instead of an internal combustion engine. The pneumatic bike will help save non-renewable sources of energy and reduce the problem of global warming. The pneumatic bike can make commuting easier and more fun. The bike reduces the required energy to ride uphill and for long distances. Ideally, pneumatic bikes will become a reasonable option for commuters to use in the future rather than vehicles that use fossil fuels.

A pneumatic bike has an engine, camshaft, sprocket, hose, cylinder, regulator, clamp, and stand. The regular bike sprocket will be attached to the engine camshaft. The stroke of the camshaft will be powered by the pneumatic cylinders. Pneumatic hoses will be attached to help pressurize the air. The air tank is the container that is filled with the fuel, which will be the pressurized air. The regulator on the bike controls the pressure of the air that enters the engine. The clamp will hold the cylinder into place. The stand will hold the engine in place behind the bicycle seat.

The bike operates from the reciprocating piston of the pneumatic cylinder that drives the crankshaft. The pressure pushed through the cylinder will add torque to the bike itself. The speed of the bike is regulated through a metering valve that meters the airflow inside the cylinder. Braking is achieved from the metering valve which stops the airflow.

Some of the features of the pneumatic bike include being pollution-free, it conserves gas, has dynamic braking, and exhausts only air back into the atmosphere. Pneumatic bikes are less costly than primary methods of transportation. The bike is more effective than standard bikes. Pneumatic bikes require little manufacturing and maintenance cost. The air tank in the bike can be refilled in relatively less time than batteries can be recharged for an electric bike.

Design Objectives

The bike we will use for our design is a two-wheel bike frame as our base. The main objective that we focused on was to create a pneumatic-powered bike that can carry a 140lb person while traveling a 5-deg incline at a working pressure of 150psi. The second main objective is to make sure that the system keeps at a constant working pressure with a pump. The next objective is that the rider can ride the bike safely. The rider can safely operate the airflow while having the switches within easy reach of the rider. The team decided to work with a belt-driven direct drive system making it easier to operate and maintain compared to the chain-driven system. Using a belt would remove much of the maintenance requirements like oiling the chains and sizing them to the correct size. In using a belt, the piston is also allowed to have error and slippage instead of destroying a chain assembly. To summarize the objectives of our project:

1. Design a pneumatic controlled bike that can carry a 140lb person while traveling a 5-deg incline at a working pressure of 150psi
2. Keep the system at constant working pressure with a pump.
3. Design a bike that is safe and user-friendly.
4. Use a belt-driven drive shaft to drive the gears.
5. To drive the bike with mechanical advantage.
6. Have a minimum of maintenance and repair work.

Technical Approach

The technical approach in building the pneumatic bike started with surveys sent to multiple groups on various identifiable characteristics of how a pneumatic bike would operate, and how pedestrian travel can be enhanced from it. After receiving survey results, the theoretics of the pneumatic bike is performed. The theory of the bike is based on five main components - the friction and forces acting on the bike, the gear ratio, the piston, the tank, and the pump.

Identifying Customer Needs

Before determining any specific customer needs, we performed theoretical calculations on a typical bicycle body. These calculations are shown below and were programmed in excel to allow for modification of independent parameters. Doing this allowed us to get a general idea of how to proceed when identifying customer needs and target specs.

To identify customer needs, we went out and surveyed different people among our family, friends, and campus groups - specifically Bearcat d&d, ChemE Cats, and Bearcat Board Games. A total of 50 surveys were returned and the results were input into a house of quality.

5-Jan	1	2	3	4
Light weight bike	5	5	4	5
Component Safety	4	5	5	5
Manueverable with gas tank	5	5	4	4
User friendly	4	5	5	5
Travel longer distance with less effort	5	5	5	5
Less effort while climbing an incline surface	5	5	5	5
Cost of the bike	4	4	4	4
Pneumatic driven	4	4	3	4
Belt driven instead of chain driven	3	2	2	3

Figure 1: Customer Survey with the first 5 results and the Specifications

Identifying Target Specifications

Determining Torque and Friction:

Bike Characteristics

Bike Weight (lb)	25
Aft Tire distance from Fore Tire (ft)	3.33
Rolling Friction Coefficient	0.008
Tire Diameter (ft)	2.25
Drag Force (lb)	4.4
Unit Weight (lb/ft)	2.68
Incline (rad)	0.087267
Incline (deg)	5

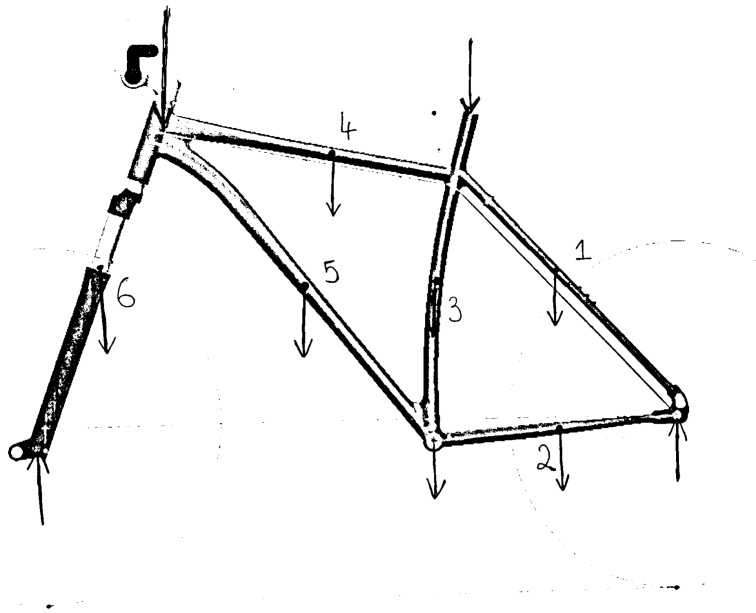


Figure 2: Free body diagram

Drag force is determined using Introduction to Fluid Mechanics 5th Edition

★ Determining Torque and Friction Force

- Tube length (ft) = Sum of the length of all members
= 9.33 ft

- Unit Weight = $\frac{\text{Bike weight}}{\text{Tube length}} = \frac{25}{9.33} = 2.68 \text{ lb/ft}$

- Using the Unit Weight find the weight of each member.

- Member 1 = $1.42 \text{ ft} \times 2.68 \frac{\text{lb}}{\text{ft}} = 3.79 \text{ lb}$

- Considering each member weight, distance of each member from front tire and incline

Moment = $F \times r \cos(\theta) = 3.79 \times 2.83 \times \cos(0.087267)$
(Member 1)
= 10.7 lb.ft

Figure 3: Torque and Friction force calculation

Besides the member weight, there are forces acting on the seat, pedals, handle, and the weight of the pneumatic assembly as shown in figure 1. Similar to the members of the bike, the distance of each external force was measured with respect to the front tire.

Member	Length (ft)	Distance from Fore Tire (ft)	Force/Weight (lb)	Moment (lb*ft)
1	1.42	2.83	3.79	10.70
2	1.33	2.67	3.57	9.50
3	1.50	2.42	4.02	9.69
4	1.67	2.00	4.47	8.90
5	1.75	1.42	4.69	6.63
6	1.67	0.67	4.47	2.98
Seat		2.75	120	328.74
Pedal		1.54	20	30.68
Pneumatic Assembly		3.75	80	298.86
Handle		1.00	50	49.81

$$\begin{aligned} \text{Force on the rear tire} &= \frac{\text{Sum of all moments}}{\text{Distance between rear and front tire}} \\ &= 227.18 \text{ lb} \end{aligned}$$

$$\begin{aligned} \text{Force on the front tire} &= \text{Sum of all forces on bike} - \text{Force on rear tire} \\ &= 67.82 \text{ lb} \end{aligned}$$

$$\begin{aligned} \text{Total friction force accounting incline} &= 227.18(0.008)\cos(0.087) + \\ & \quad 67.82(0.008)\cos(0.087) \end{aligned}$$

$$\begin{aligned} \text{Total friction force} &= 2.35 \text{ lb} \end{aligned}$$

$$\left(\begin{array}{l} \text{Friction force} = \\ \text{Force} \times \text{Rolling} \\ \text{friction} \\ \text{coeff.} \end{array} \right)$$

Figure 4: Total friction force calculation

$$\text{Inclined force} = \text{Sum of all force on bike} \times \sin(0.087267)$$

$$\text{Inclined force} = 25.71 \text{ lb}$$

$$\begin{aligned} \text{Total Force acting against the bike} &= \text{Friction force} + \text{Inclined force} \\ &= 28.06 \text{ lb} \end{aligned}$$

$$\text{Rear tire torque} = \left(\text{Total force against bike} + \text{Drag force} \right) \cdot \frac{\text{Tire diameter}}{2}$$

$$\text{Torque} = 36.52 \text{ lb.ft}$$

Figure 5: Torque calculation

Determining Gear Characteristics:

With torque required determined from worst-case assumptions, the gear ratio is then determined for the bike. The gear train is as follows: Driving gear - Gear where the piston is directly attached via clevis. Driven gear - Gear attached to aft wheel of the bike. Tandem Gear - the aft wheel of the bike. Idle gear - A misnomer for the driven gear, in this document, they are used synonymously.

Drive Gear Diameter (ft)	0.5625
Idle gear diameter (ft)	0.174
Actuation frequency of piston (Hz)	4

★ Determining Gear Characteristics

$$\text{Gear Ratio} = \frac{\text{Drive gear dia.}}{\text{Idle gear dia.}} = 3$$

$$\begin{aligned}\text{Torque on Secondary gear} &= \frac{\text{Idle gear dia.}}{\text{Tire dia.}} \times \text{Rear tire torque} \\ &= 2.82 \text{ lb.ft}\end{aligned}$$

$$\begin{aligned}\text{Torque on primary gear} &= \frac{\text{Drive gear dia.}}{\text{Tire dia.}} \times \text{Torque on secondary gear} \\ &= 0.71 \text{ lb.ft}\end{aligned}$$

$$\text{Drive gear RPM} = \frac{\text{Actuation frequency of piston}}{2} \times 60 = 120$$

$$\begin{aligned}\text{Secondary gear RPM} \\ \text{or} \\ \text{Tire RPM} &= \text{Gear Ratio} \times \text{Drive gear RPM} \\ &= 387.93\end{aligned}$$

$$\begin{aligned}\text{Bike Speed (mph)} &= \text{Tire RPM} \times (\text{Tire Dia.} \times 0.5) \times 0.011363 \\ &= 5 \text{ mph}\end{aligned}$$

Figure 6: Gear characteristics

Determining Piston Required:

After the desired gear ratio is determined and the torque required at the drive gear, we need to determine the piston that can support the linear force required to move the drive gear. This is shown sequentially below.

Below: Input for Piston angle to determine peak force required

Extended Arm angle to gear (deg)	14.72
Gear Pin Angle from Gear Center (deg) (Extended)	31.73
Retracted Arm angle to gear (deg)	12.22
Gear Pin Angle from Gear Center (deg) (Retracted)	17.92
Bore size (in)	1.0625
Piston operating pressure (psf)	11520

★ Piston Characteristics

$$\text{Piston Output force when extended} = \frac{\text{Torque required at primary gear}}{\text{Drive gear dia.} \cdot \sin\left(\begin{array}{l} \text{gear pin angle} \\ \text{from gear center} \end{array} - \begin{array}{l} \text{Extended arm} \\ \text{angle to gear} \end{array}\right)} \quad \left(\begin{array}{l} \text{Angles in} \\ \text{radians} \end{array}\right) = 4.16 \text{ lb}$$

$$\text{Piston Output force when retracted} = \frac{\text{Torque required at primary gear}}{\text{Drive gear dia.} \cdot \sin\left(\begin{array}{l} \text{gear pin angle} \\ \text{from gear center} \end{array} - \begin{array}{l} \text{Retracted arm} \\ \text{angle to gear} \end{array}\right)} = 12.60 \text{ lb}$$

$$\begin{aligned} \text{Volume (gal)} &= 3.142 \times \text{Bore size}^2 \times 0.25 \times \text{Drive gear dia.} \times 7.48 \\ &= 0.026 \text{ gal} \end{aligned}$$

$$\begin{aligned} \text{Flow Rate (gal/min)} &= \text{Volume} \times \text{Drive gear RPM} \times 2 \\ &= 6.2 \text{ gal/min} \end{aligned}$$

Figure 7: Piston Characteristics

Pneumatic Bike - Piston

- Bimba's Piston chart, displaying output force in pound force for different bore sizes. An appropriate piston is indicated, it is possible to downsize further, decreasing flow rate to increase duration

Size (Part No.)	Power Factor		Force(#) @ 60psi		Force(#) @ 80 psi	
	Extend	Retract	Extend	Retract	Extend	Retract
5/16" (007)	.07	.06	4.2	3.6	5.6	4.8
7/16" (01)	0.15	.12	9.0	7.2	12.0	9.6
9/16" (02)	0.25	.22	15.0	13.2	20.0	17.6
3/4" (04)	0.44	.39	26.4	23.4	35.2	31.2
7/8" (06)	0.60	0.55	36.0	33.0	48.0	44.0
1-1/16" (09)	0.89	.81	53.4	48.6	71.2	64.8
1-1/4" (12)	1.23	1.08	73.8	64.8	98.4	86.4
1-1/2" (17)	1.77	1.62	106.2	97.2	141.6	129.6
1-3/4" (24)	2.41	2.21	144.6	132.6	192.8	176.8
2" (31)	3.14	2.83	188.4	169.8	251.2	226.4
2-1/2" (50)	4.91	4.60	294.6	276.0	392.8	368.0
3" (70)	7.07	6.63	424.2	397.8	565.6	530.4
3-1/4" (83)						
4" (125)						

Figure 8: Determining Piston from Bimba's Original Line piston Chart

Determining Tank and Pump Characteristics Required:

With the calculated gear characteristics and piston characteristics the tank and pump calculations are calculated with the pulley and piston values and some constants assumed as shown below.

Gas constant (ft*lb/slug*R)	1716.49
Temperature (R)	529.67
Tank pressure (psf)	21600
Tank volume (gal)	2.5

★ Tank and Pump Characteristics

$$\text{Density in tank (slug/ft}^3\text{)} = \frac{\text{Tank pressure}}{T_{\text{emp.}} \times \text{gas constant}} = 0.024 \text{ slug/ft}^3$$

$$\text{Density in piston (slug/ft}^3\text{)} = \frac{\text{Piston operating pressure}}{T_{\text{emp.}} \times \text{gas constant}} = 0.013 \text{ slug/ft}^3$$

$$\text{Air in tank} = 2.5 \times \text{Density in tank} = 0.059 \text{ slug}$$

$$\text{Air in piston} = \text{Volume} \times \text{Density in piston} = 0.0003 \text{ slug}$$

$$\text{Iterations supplied by full tank} = \frac{\text{Air in piston}}{\text{Air in tank}} = 180.92$$

$$\text{Operation time} = \frac{\text{Iterations supplied by full tank}}{\text{Drive gear RPM}} \times 60 = 90.4 \text{ s}$$

Figure 9: Tank and Pump Characteristics

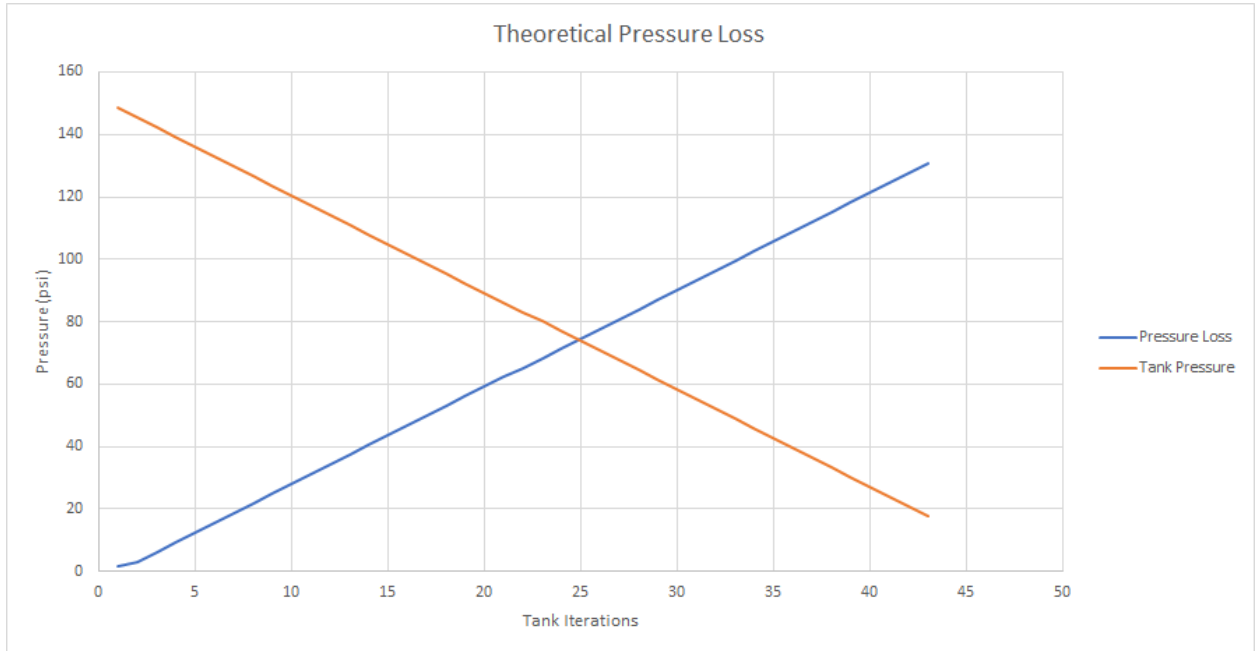


Figure 10: Pressure Loss from the tank with each piston actuation

The tank lifetime must be calculated in a manner that accounts for changes in pressure in the entire system. The mass of air the piston expels is based on the pressure of the system. To attain an accurate lifetime, Pressure loss after each actuation is accounted for in the tank, and the amount of air the piston expels is lessened in a new iteration. The operating pressure of the tank is about 20 PSI, meaning the tank will have about 42 iterations, or 25 seconds of the operation time, not the initially calculated 90 seconds, which does not account for changing pressure.

Design Concepts

In the initial stages of considering design concepts, three separate frame designs came into consideration.

Design 1:

Frame Design 1 includes a piston frame mount that fixes the pneumatic pulley in place and fixes the piston head to secure it to the bike frame. In this design, the crankshaft that goes through the piston mount and the extra pulley would be unable to withstand a pressure above 80 psi. The design of the bike would be strong enough to carry the gas tank after being strapped on. In this process, the frame clamps will be 3D printed, the frame will be CNC from an aluminum sheet, and the printed clamps would be bolted on after being wrapped onto the frame of the bike.

While this design is practical in manufacturing, it is not ideal in accomplishing the end goal for the project. This design wouldn't provide significant power through pneumatics and would only last a short timespan.

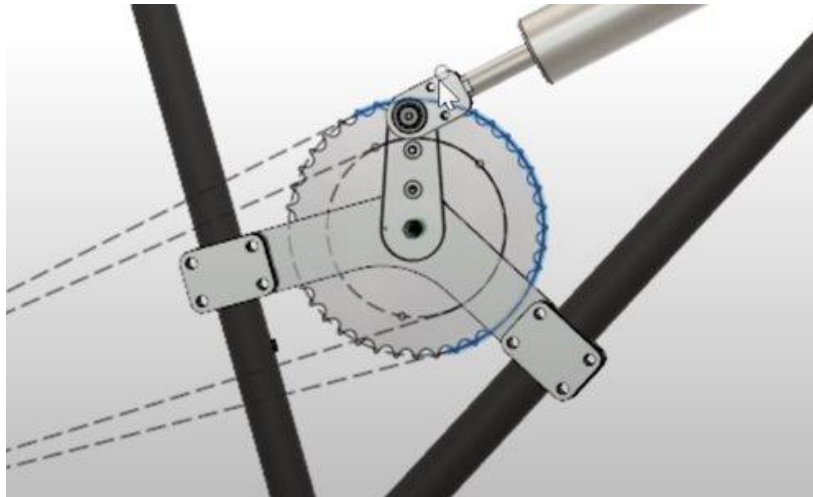


Figure 12: Frame Design 1

Design 2:

Frame design two is a design that would be intended to be machined and wouldn't be found on the market. The design would require modifying an entire frame and would be difficult to accomplish in a limited production time frame. This design would be very dependent on air tank capacity and is limited in power due to being unable to retrieve and reuse air. The design is intended to utilize the front basket to store the gas tank. The back seat is utilized to mount 2 pistons. The drawback of the design is that it is difficult to maneuver and to balance due to the heavy gas tank.



Figure 13: Frame design 2

Design 3:

Frame Design three is designed to run on the duration of the pressure tank. Stability and high speed from the design come from the gear ratio, the pneumatic pulley that connects to the smaller ratio pulley that would, in turn, drive the main pulley off the bike. The design operates similarly to the first design where it utilizes the back seat to mount the gas tank. Two pistons will be built on the mainframe but they will be placed symmetrically apart to a platform near the handlebar area. The extra pulley will be placed on a metal piece that is secured through clamps on the frame of the bike acting as a bed for the pulley to be mounted on.



Figure 13: Frame design 3

Selecting Design Concept

Our chosen bike concept was to design the bike to have the tank on the front of the bike, mounted atop of the middle of the handlebars. At the back of the bike, under the seat is the battery to power the pump and relay switch. Behind the battery, is a double-action piston powering a mounted drive pulley between two pieces of plywood with a linear rod. A belt is wrapped around the pulley and onto a belt tensioner to keep the belt tense and tight. These connect to a smaller pulley on the rear tire.

Early in the concept of creating this specific design, a double-action piston design vs a single action was debated. Either the bike would have a one-way airflow in the piston or it would have another port that would act as a plunger. Selecting a double-acting piston proved to be the most beneficial for airflow as it helps improve efficiency in giving the piston



Figure 14: Final design

Project Management

Timetable

	August				September				October					November				December				
Weeks start date	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	1				
Research/concepts																						
Kick-off																						
Concept selection																						
calculations																						
Circuit design																						
Part selection																						
Order part																						
Modification design																						
Review and proof concept																						

Figure 15: Time table

Deliverables

We will provide the customer with a fully functional bike that matches the design objectives. The bike will be installed beforehand and also tested. A user manual will be provided for instruction and maintenance. The gas tank will not be installed and provided for safety reasons. Each component will be wrapped in foam pipe insulation and tape to make sure nothing moves out of their places or is damaged.

Budget

NFPA provided the team with 2,100USD to complete the project, also funding the advisor for the pneumatic parts. Bimba funded the team by providing around 500 USD of any applicable material from their shop.

Bill of Materials

Parts	Supplier/ manufacturer	Quantity		Price
6KU Bike	Amazon	1		319.93
PAKRAK Rack	Amazon	1		32.98
Schwinn Rack	Amazon	1		25.37
Idle Pulley	MDS	1		768.75
Drive Pulley	MDS	1		
2.5 gallon Air Tank	Viair	1		70.61
3.82 CFM Pump	GSPCN	1		78.99
12V Lawn Mower Battery 300 CCA	Country TUFF	1		30
1 - 1/16" diameter piston	BIMBA	1		25
Carbon motor Brush	salvaged	1		0
1" thick plywood	salvaged	1		0
½ * 56" belt	Amazon	1		11.43
Belt tensioner	Amazon	1		15
8mm diameter shaft		1		10
2 way 5 position valve	BIMBA	1		30
Liquid filled pressure gauge	Amazon			15.94
90005 Tank Port Fitting Kit				
Plug 1/4 NPT	Viair	1		11.96
90007 Air Source Relocation Kit	Viair			39.02
Detention Valve	Amazon	1		
Safety Release Valve ¼ NPT	Amazon	1		12.95
Pressure Gauge ¼ NPT	Amazon	1		15.94
Plug ¼ NPT (in Tank Port Fitting Kit)	Amazon	1		
½ to ¼ NPT Reducer	Amazon	1		5.03
3/8 to ¼ NPT Reducer	Amazon	1		9.47
¼ NPT to ½ PTC	Amazon	1		22.76
½ NPT check valve	Amazon	1		36
½ NPT m to ½ NPT m Female Adapter	Amazon	2		1.86
2 Way 3 Position Push Button	Amazon	1		118.51
Polyurethane Tubings	Amazon	1	Spool	
Perforated Hanger Straps	Amazon	1	Spool	
Heavy duty Zip ties	Amazon	10		
3/8 NPT m female to 1/4 NPT adapter	Leginess	1		10.15
Bolts		15		
Screws		12		
Linear bearings		2		
M12 Screw thread		4		
Aluminum Tig Weldeing Rod				33.11
3D Printed Spacer		1		0.03
				1750.79 Total

Figure 16: Bill of Materials (items in yellow highlight were self-provided)

Manufacturing

Air tank attached to the bracket at the handle

The air tank that was supposed to be used was 1 gal. Viair did not have a stock of 1 gal air tanks so a 2.5 gal tank was selected instead. This tank was much more slender and less wide, which was less optimal to work with. The tank is fitted with 2 plugs, a pressure gauge, a 175lb safety release valve, and a switch assembly used for the piston actuation (see *Piston Actuation System* in *Manufacturing*)

Due to the size of the air tank and the configuration of the bike design, we have decided to attach the air tank to the steering handle. In order to do this, some procedures needed to be done to make room for both the air tank and the steering handle while keeping maneuverability and ergonomics feasible. We removed the handle from the head tubes. The fore rack is attached to the head tubes and secured using nuts and bolts. Next, the handle is attached to the rack at the front. The air tank is then attached to the rack.



Figure 18: Top View of Tank Setup



Figure 19: Profile of Tank Setup at side view

Wooden panels replacing theoretic brackets

Instead of using the designed brackets to secure the drive pulley and the belt tensioner, we used 1-inch wooden panels. The panels are fitted on both sides at the bike's flanks. During the process of manufacturing and testing, the wooden panels are stronger and versatile enough to be mounted, screwed, and attached to different components, parts of the bike without any limitations. Once the design is complete and the testing yields promising results, we will trim the panels to the right shapes to reduce weight, eliminate excessive material, blockage, and improve appearance. In our original design, we chose to use steel brackets to secure the piston, drive gear, and other components. However, due to time constraints and the inability to easily access the machine shop, we have decided to use wooden panels as a base to attach components.

Even though the panels are heavier and less stable (spongy and porous), they allow for a larger amount of error. Moreover, they are very convenient when it comes to testing multiple positions of piston and drive pulley positions and angles, which is one of the main reasons we decided to use them. The panels can be easily cut and drilled and do not require any machining or careful tolerances. In short, the wooden panels allowed for flexible hole locations. We recommend future senior design groups use wooden panels in locating holes for machining in steel or aluminum.

Drive pulley(fittings, stabilizing)

The drive pulley is what the piston is connected to by a piston clevis. The drive pulley is built to have a pin that goes through the entire piston and out the other end so the clevis can apply force with stability.

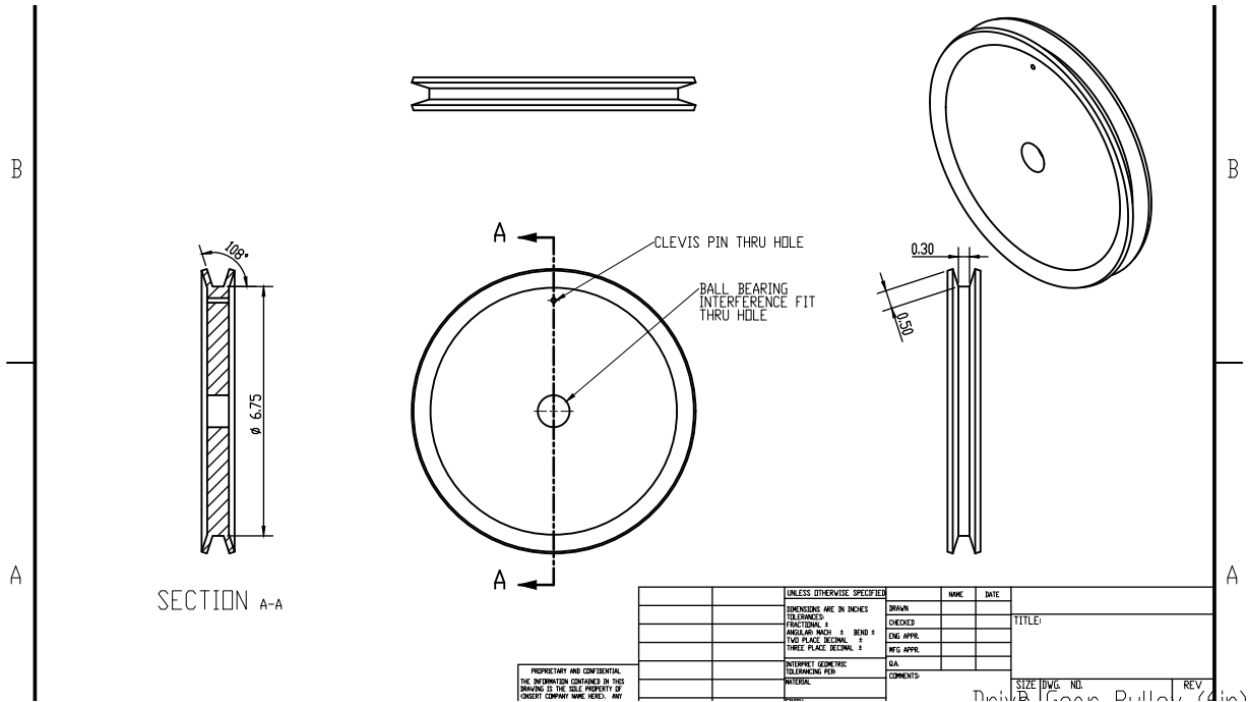


Figure 20: Drive Pulley Design taken at the machine shop

The drive pulley was commissioned to be built by ModernDie Systems as the university's machine shop was still closed. Due to misunderstandings and miscommunication, instead of the desired material of aluminum to create the drive pulley, the MDS shop used steel. This makes the drive pulley much more difficult to work with because it has much more momentum and weight such that there is a large moment force on the pulley shaft that causes the pulley to warp and move at an angle.

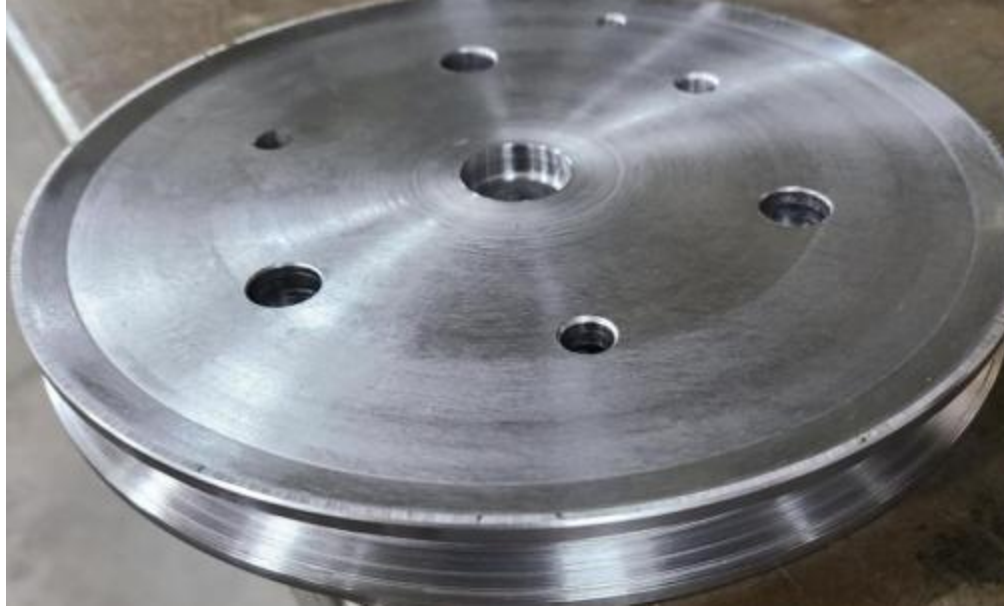


Figure 21: Drive pulley Machined by MDS

The pulley was designed to be used with a 1/2"x56" V belt. The V belt fully sinks into the wedge of the piston when under tension, maximizing the contact friction. The maximized friction with high tension allows the gear to handle increasing force without slipping. The final diameter of the drive pulley is .5625ft internal diameter. The internal diameter is what the bottom of the V belt rests upon and is what is used in the theoretic calculations.

The drive pulley has a design flaw in which the piston clevis causes the piston to pass very close to the center, preventing any stabilization methods to be used on the other side of the piston. Because of this, linear bearing and Loctite were used to stabilize the piston using only one side. The moment that the drive pulley must withstand is too high that warpage and instability are created to a problematic degree, causing the piston to bind and behave irregularly.

A linear bearing was welded directly onto the drive pulley, fixing most of the instability, and another linear bearing was screwed into the wood panel, making the pulley very rigid. Lock-tight was used to hold the piston bearing's inner diameter and

shaft together in order to prevent the shaft from fallout out of the piston.

There were multiple iterations of design for the pulley's shaft because of instability. The first was to use a threaded rod that fit loosely in the bearing and lock it with locknuts. This still allowed the piston to shake far too much to be stable. The next iteration was to use PTFE tape to reduce the gap at the shaft and bearing interface. This worked well but it was still not stable enough. The last interaction was to buy a polished steel rod that was the exact diameter of the shaft's inner diameter. This would have been perfect but the shaft was .001 in smaller which did not create an interference fit. However, the stability of the drive pulley was much more manageable, and was able to work with the system.



Figure 22: Warpage from the Threaded Rod

The drive gear has a linear bearing welded onto its face, effectively locking the bearing in place. Aside from this, it provides great stability for the shaft, guiding it up to

This pulley has a left-hand thread on the inside bore, allowing it to be screwed into the bike's direct-drive side - Fully replacing the direct-drive chain gear. The driven pulley is also counterbored, allowing us to re-apply the lock on the right-hand threads so the pulley cannot unscrew itself from applied forces.

After building the pulley and applying it to the wheel, there was still movement on the right-hand thread, this allowed the idle pulley to slam against the lock because the counterbore was too deep. To fix this issue, a spacer was 3d printed in PLA and inserted into the counterbore, allowing the pulley to press up against it and lock in place.

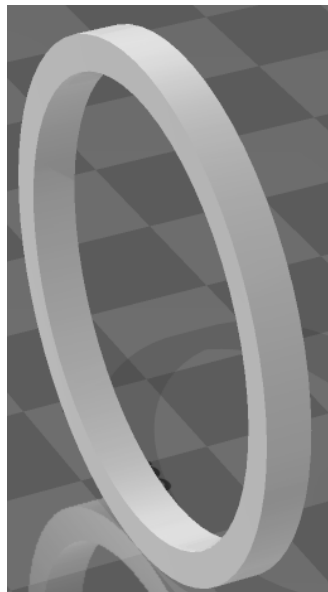


Figure 24: Spacer for pulley counterbore

The driven pulley was created in steel, but it only weighs 2.3 lbs and the steel material for threads was better for the system than aluminum. This is because it provides more hardness, allowing it to slightly cut into its threads against the lock and the end of the bike and remain completely rigid.



Figure 25: Assembly of the aft wheel

Belt and Removal of Bike Chain

Using a V belt instead of a chain or even a timing belt was a decision made for safety. A timing belt and especially a chain with a piston setup at 150 psi could break or snap under heavy tension instead of just slipping. Using a V belt will allow slippage when absolutely necessary, allowing the system to fail without harsh or dangerous results. Because the driven pulley is built to be a direct drive instead of a freewheel, slipping is especially important to maintain safety and structural integrity.

The V belt used is a 1/2" x 56" belt used for electric motors and tractors. It is made of rubber and felt with copper thread inner lining. The V shape allows it to sink into a properly designed pulley to maximize surface area in contact, increasing frictional force.

The V belt must be kept under high tension in order to withstand the high amount of force used in the calculation. This is done with a belt tensioner. Care must be taken into consideration of how much tension is applied to the belt because it can warp the assembly and cause instability and unpredictability.

Safety & Control

The air was maintained in an air tank at 150 psi. Connected to the tank is an adapter with a push button. The adapter serves the purpose of a release valve and it acts as a FNPT-FNPT adapter to the two-way five-position valve. Connected to the tank is a 1/4 MNPT - 1/8 MNPT adapter.

From the adapter is the two-way five-position switch with an attached relay switch. The switch itself has an input, two exhaust ports, and two outputs. The input is receiving tank air pressure. The outputs connect to both ends of the piston. Air flows through output A while B is closed. B is the exhaust. The attached relay switch is an electric switch that controls the airflow. It is powered by a battery.

On the bike handle is a switch that controls the two-way detention valve. The two-way detention valve acts as a break in the piston's line. Leaving the switch in the open position allows airflow to continue. Toggling the switch plugs the airflow from the tank and depressurizes the piston, exhausting any air in the piston and allowing it to act as a dashpot, effectively slowing the bike. Depressurizing the piston is important so the piston does not lock the gear at the full extent or retract and shock the entire system.

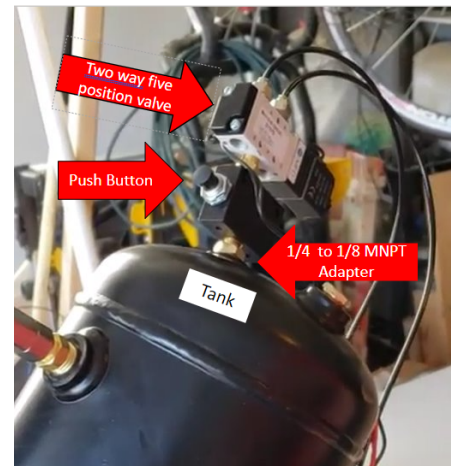


Figure 26: Air Tank Control System

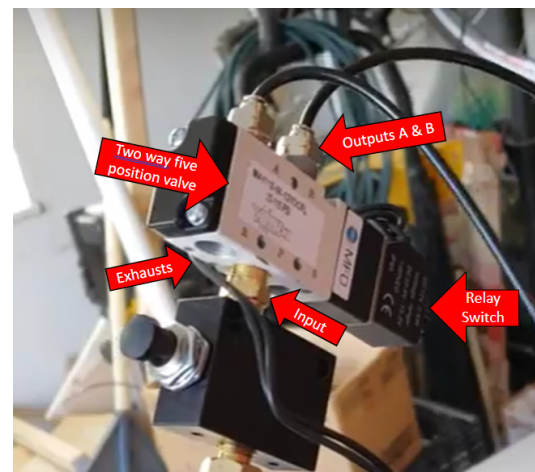


Figure 27: Two way five position switch



Figure 28: Two way detention valve

Connected to the piston is the Drive Gear. The drive gear has insulation tape wrapped around half of the drive gear. When there is contact with the tape, there is no current and the piston is told to retract and pressurize. Contacting metal creates a current and communicates to the piston to extend and depressurize. A carbon motor brush has a spring in it to allow constant contact with the gear. A linear bearing is included to keep the gear stable.

To apply the belt onto the drive gear, the belt is wrapped around the gear and over the belt tensioner. The drive gear has a groove to hold the belt. To wrap around the belt tensioner, it must be lifted and then released once ready.

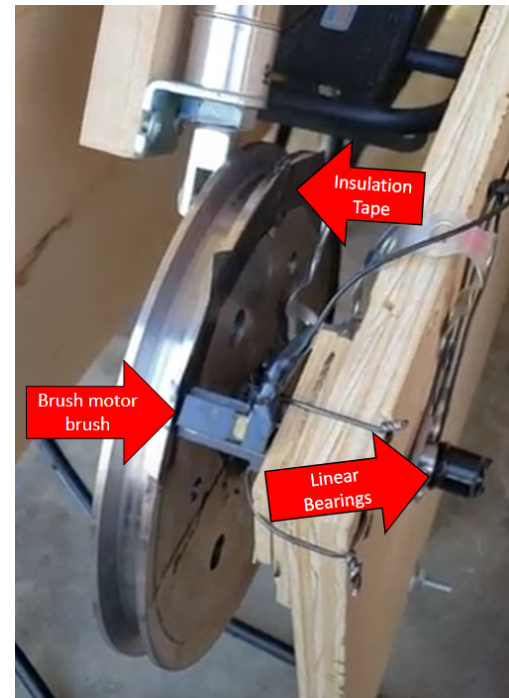


Figure 29: Drive Gear System

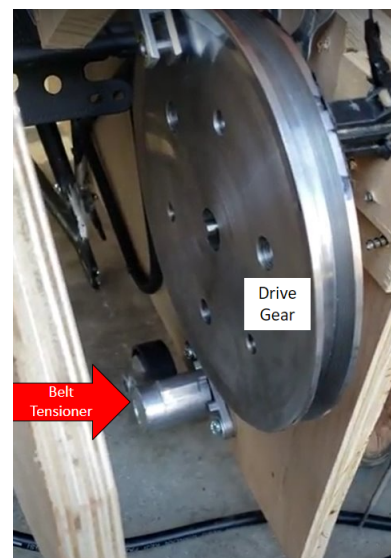


Figure 30: Drive Gear System

Parts function overview

Drive Gear, driven gear, tensioner, belt:

The Drive gear is connected to the driven gear, with a tensioner in between them and a belt connecting the entire system. The drive gear turns by the linear actuation of the piston and with a 3.2 gear ratio, the driven gear will turn 3.2 revolutions as the drive gear turns one revolution. The belt tensioner should keep the belt very tight and maximize friction against all the components in the system. This will allow the drive gear to rotate the driven gear. The driven gear will have high friction caused by the tandem gear's applied resistance.

Piston

The piston will be able to function at a minimum pressure of about 20 psi. Two actuations of the piston will rotate the drive gear once. This means the speed of the bike is based on the actuation frequency of the piston. The actuation frequency of the piston is based on the current pressure of the system and the size of the fittings.

Tank and pump

The Tank will act as a buffer for the pump. The tank will be small enough to be mountable on the fore or aft without any difficulty to the rider. The pump will keep the tank in equilibrium by constantly supplying it with enough air at full pressure that the tank will not lose enough pressure to visibly slow the piston actuation frequency.

Testing

The bike was able to travel about 50ft up a 5deg incline, but due to instabilities, it became bound and could not go any further without intervention. The applied force of the piston at 150 psi was around 134lbs, which is close to what was stated in Bimba's power factor.

The distributed weight of a 150lb man on the pneumatic bike was about 53% on the seat, 16% on the handles, and 31% on the pedals. This weight distribution was used in the calculations. The placements of the components may not have been ergonomically optimal, consider making a pneumatic tricycle or quad so balance and weight would be negligible at the cost of increased rolling friction.

Further testing was done to validate the results of the theoretics:

Tank and Pump: With a full tank and no pump, the tank could last 22s before the pressure is too low to move the bike, giving an error of about 12%. This is likely from errors with the most likely due to leaking from the system. The pump was strong enough to put the tank at 200 psi so it had to be shut off at around 175 psi to keep from overpressurization.

Gearing Characteristics: The gear ratio is accurately determined by rotating the tandem gear and observing how many actuations the piston makes to find the rotations of the drive gear. One rotation of the drive gear took about 3.23 rotations of the tandem gear, resulting in a gear ratio of 3.23.

Actual Part Function

Drive Gear, driven gear, tensioner, belt:

The drive gear was difficult to maintain stability in. Warp at the drive gear caused the piston attached to bind. The driven gear worked great, remaining rigid and allowing the tandem gear to turn with ease. The belt tensioner may have been too strong because of the extreme difficulty at stabilizing the drive gear. The kevlar and copper-lined belt worked very well.

Piston

Because the actuation frequency of the piston is based on the current pressure of the system and the size of the fittings, this 1/8 NPT double-acting piston worked at an underwhelming 3.7 Hz, making the linear speed of the bike about 6mph.

Tank and pump

The tank and pump did an excellent job at keeping the pressure in equilibrium. Because a 1gal tank was not available, we had to use an extremely long and bulky 2.5 gal tank, making the location we had to put it at the bow of the bike, causing turning and agility difficulties.

Conclusion

The Drive pulley was too large and bulky to effectively stabilize, but the linear bearings had very high effectiveness at stabilization. The greatest problem was the aluminum, which was extremely difficult to weld any support structures onto. Wood Panels should have been temporary and used to locate bolt holes and component locations for steel supports. The drive pulley should have been 66.25% lighter because it should have been aluminum.

The tank and pump worked great, and the pump did an excellent job at keeping the tank in equilibrium. The Piston was also excellent at its purpose in the system and was also very stable as a component. Safety and care should be taken when handling a piston with 150psi of operating pressure, as the rod is also close to 150 pounds of force in pushing or pulling.

The method used to determine the state of the relay switch was very effective but not completely stable, as the stability of this method relied on the stability of the drive pulley, which was problematic. The belt tensioner was the reason the bike could pull the weight, but also the reason it made it nearly impossible to stabilize the pulley using the materials for this project. Great care should be taken, for once the belt tensioner is in place, the bike will not be easily stopped should the system start, which can cause a safety hazard to anyone in the way of the bike or the bike itself if it should fall.

In the future, we would construct the bike with a more stable and sleek build with brackets rather than wooden panels. We would also like to build the bike in a way where the user could conserve the airflow off and on mid-ride without worrying about the safety of the bike or user. Finally, we would like to shoot for a higher weight load than a 140lb person.

Source Cited/Referenced

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