جامعة الأمير محمد بن فهد
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Department of Mechanical Engineering

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Senior Design Project Report

Design of a Pneumatic Powered Bicycle

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

Team Members

	Student Name	Student ID
1	Abdulelah Almarqabi	201400105
2	Sohaib Imran	201303504
3	Salman Siddique	201303877
4	Mohammad Faraaz	201400318
5	Abdullah Bashir	201400533

Project Advisors:

Advisor Name: Dr. Muhammad Asad

Co-Advisor Name: Dr. Nader Sawalhi

Abstract

The world today heavily relies on fossil fuels for power consumption. Each and every day the demand keeps increasing but the supply is only available in a limited quantity. It is only a matter of time that fossil fuels will be completely used up and no longer available. Thus, a lot of research and experimentation is being done in various fields, which rely on fossil fuels, to come up with alternatives. Transportation is one area that uses a lot of fossil fuels and it needs to be addressed quickly. One area of interest is powering motorbikes using pneumatic systems. Pneumatic systems are those that work with pressurized air as their source of fuel.

The objective of this project is to design a pneumatic powered engine for bicycles. Contrary, to motorbikes the purpose is to get boosted power (thrust) only for limited period of time when required. Examples may include doing uphill cycling, carrying extra weight, closing in to the finishing line in racing, etc. The project mainly involves proper selection of power generator (engine), air tank, pneumatic hose, and air regulator. Design and modification of adapters, camshaft, and finally the proper installation of parts on bicycle are also salient features of the project. The ultimate goal is to have a green environment by reducing emission gasses and reducing the reliance of fossil fuels.

Acknowledgement

We would like to express our sincere gratitude to our advisor Dr. Muhammad Asad for his continued support and contribution throughout our project. Also, we wish to appreciate the efforts of our co-advisor Dr. Nader Sawalhi for sharing his expertise, guidance and encouragement extended to us. We place on record, our sincere thank you to Dr. Faramarz Djavanroodi, chair of the Mechanical Engineering Department at PMU, for the continued encouragement. We take this opportunity to express gratitude to all of the Department faculty members for their help and support. We also thank our parents for the unceasing encouragement, support, and attention.

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Chapter 1: Introduction

1.1 Project Definition

Fossil fuels meet most of the world's energy demand today, and they are being depleted rapidly. Their combustion leads to production of greenhouse gases which leads to climate change. Most of the transportation vehicles use fossil fuels as their primary source of energy. Eco–friendly commuting means such as bicycle requires us to do work to provide energy, and most of us don’t want to reach our destination exhausted.

Our approach to this problem is to design a pneumatic powered engine which will utilize compressed air as its primary source of energy. This engine will provide a thrust when cycling uphill or assist in normal riding. The assist from the engine will improve the overall riding experience and also help the rider reach their destination without using up a lot of their energy. The reason why air is being used as the primary fuel is because it is abundantly available and the cost of using air as fuel is relevantly cheap. Using compressed air is also eco-friendly as there are no exhaust gasses.

In this project we will be modifying components so that they may fit a normal bicycle. Components such as an engine, air tank, pneumatic hose and regulator. Air tank will store the compressed air awaiting entry into the chamber of the air engine. The flow will be controlled via the regulator. The engine will utilize this pressurized air to produce the necessary power.

1.2 Project Objectives

The following are the objectives for the project:

- To design a pneumatic powered engine for a bicycle
- Designed to achieve a thrust when operated

1.3 Project Specifications

The pneumatic system can be implemented on any type of bicycle with only adjustments required for the stands. The specifications for the pneumatic system can be seen in table 1.1.

Table 1.1 Parts Specifications

Part	Specification
Engine	50cc internal combustion 4-stroke engine converted into a 2-stroke pneumatic engine
Camshaft	Modified 4-stroke camshaft to 2-stroke
Sprocket	Regular bicycle sprocket attached to the engine shaft
Hose	Pneumatic hoses used which work with pressurized air
Cylinder	Container filled with pressurized air to be used as fuel
Regulator	Used to control the pressure of the air that enters the engine
Clamp	Used to hold the cylinder in place by clamping it with the bicycle frame
Stand	Used to hold the engine in place behind the bicycle seat and is supported with vertical stands to hold the weight

1.4 Applications

The pneumatic powered bicycle can be used for many different applications. It can fit many criteria to help people in certain areas. The following are the applications for the air compressed bicycle:

- Easing the rider's efforts while riding uphill
- Using bicycles for long distance travels
- Reducing fossil fuel consumptions
- Make the bike fun and easy to commute

Chapter 2: Literature Review

This chapter focuses on the research and work done in the area of pneumatic powered systems. The background of pneumatics is discussed in detail and the theory behind it is explained. Furthermore, comparative study has been done using the literature available on the internet.

2.1 Project background

Over the past few decades, environmental concerns had been added to feasibility studies in most practices, as industries and legislation bodies had grown more aware and responsible. In the mid 1800's many designs for pneumatic locomotives had been published and some of the designs had their prototypes displayed, which can be seen in figure 2.1. However, they weren't further improved and developed as power generation had drifted towards combustion. Now scientists, researchers and industries are looking for areas where it is feasible and cost effective to implement non combustion based engines. One of the alternatives that has been looked at for centuries is the pneumatic powered engine. Pneumatic engines are engines powered by compressed air instead of fuel, and it does not involve combustion. Since most of the uses of combustion engines are in vehicles, we looked at inventions in the field of transportation. In 2013 Huang C., Hu C., Yu C. and Sung C. published an article, "Experimental Investigation on the Performance of a Compressed-Air Driven Piston Engine". In the article they discussed some of the short comings of the CAE, ranging from exess need of air flow to low perfomance in regard of speed. This pivoted us to make our engine an auxilary unit on a bicycle. [1]

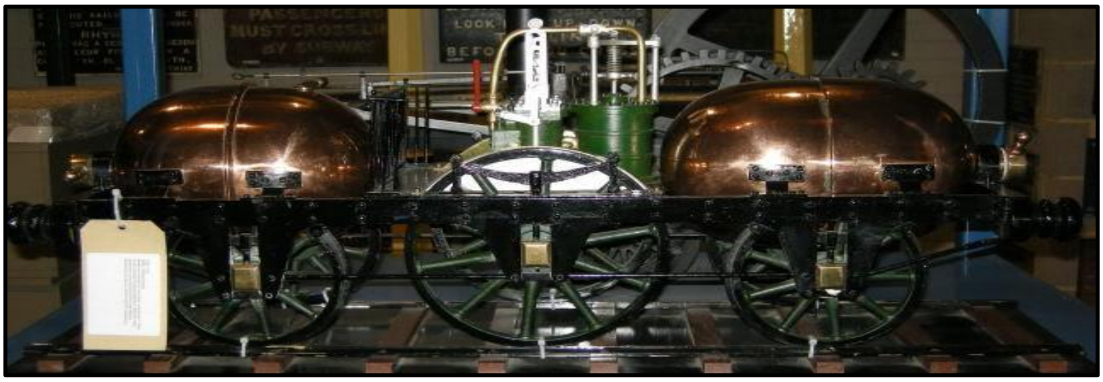


Figure 2.1Model of the Parsey compressed-air locomotive [1]

The compressed air technology is quite simple. Air is compressed into a cylinder and that air would have some energy within it. When this compressed air expands, the energy is released to do work. So this energy can be utilized to displace the piston. This is the basic principle behind the compressed air engine. An air engine is basically a pneumatic actuator that creates useful work by expanding compressed air. [2]

The simple design, compact size and the stability of pneumatic systems make them suitable for mobile applications. Pneumatic system plays a very important role in industrial system due to the advantage of low cost, easy maintenance, cleanliness, availability and cheap source [3]. The behavior of compressed air is safe, clean, simple and efficient. There are no emissions of dangerous fumes by products when the compressed air is used. It is a non-combustible, non-polluting utility. When the air at atmospheric pressure is mechanically compressed by a compressor, the transformation of air at atmospheric pressure (1bar) into air at high pressure up to 414 bar is determined by laws of thermodynamics. It states that an increase in pressure equals a rise in heat and compressing air creates a proportional increase in heat. Boyle's law explains that if volume of a gas/air halves during compression and the pressure is doubled. Charles law states that the volume of gas changes in direct proportion to the temperature. [4]

The given mass of gas occupies certain volume, or the free air has some density in free space. The molecules of air inhabit a certain volume in free space, which can be seen in figure 2.2. The molecules of air are forced to come closer by compression, it can be seen in figure 2.3. As a result, the molecules occupy less space compared to when they are free. The mass of air also increases as the molecules of air in the given volume increases along with the density. As the density increases, the pressure of air increases and thus becomes compressed air. [5]

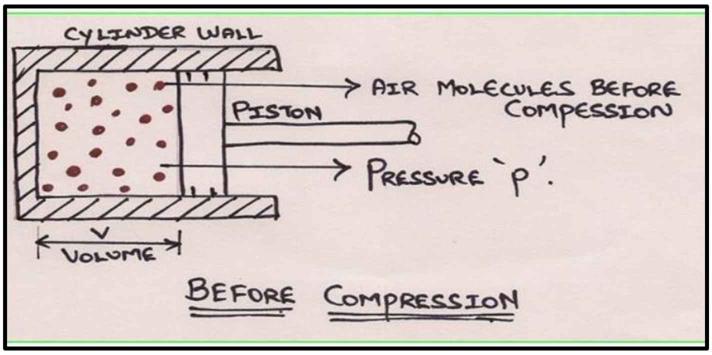


Figure 2.2 Air molecules before compression [5]

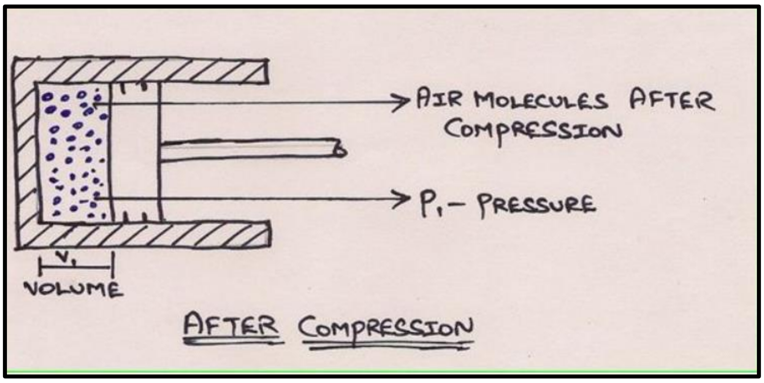


Figure 2.3 Air molecules after compression [5]

Compressed-air engine has existed in many forms over the past two centuries, ranging in size from hand held turbines with low horsepower up to several hundred horsepower. Some types rely on pistons and cylinders, others use turbines. Many compressed air engines improve their performance by heating the incoming air or the engine itself. Some took this a stage further and burned fuel in the cylinder or turbine, forming a type of internal combustion engine. One can buy the vehicle with the engine or buy an engine to be installed in the vehicle. [6]

According to Patnaik, S. (2015). "Compressed air is kept under a pressure that is greater than atmospheric pressure. The Density of air is 1.126 Kg/m3 at 1 atm (1.01325 bar). A compressed-air vehicle is powered by an air engine, using compressed air, which is stored in a tank. Instead of mixing fuel with air and burning it in the engine to drive pistons with hot expanding gases, compressed air vehicles (CAV) use the expansion of compressed air to drive their pistons. For example, the first mechanically-powered submarine, the 1863 Plongeur, used a compressed air engine. The laws of physics that the gases will fill any given space. The easiest way to see this in action is to inflate a balloon. The elastic skin of the balloon holds the air tightly inside, but the moment you use a pin to create a hole in the balloon's surface, the air expands outward with so much energy that the balloon explodes. Compressing a gas into a small space is a way to store energy. When the gas expands again, that energy is released to do work. That's the basic principle behind what makes an air cargo". [6]

2.2 Previous Work

2.2.1 Pneumatic Bicycle

One of the first pneumatic vehicles that were made and got patented is Roy J. Meyers's Air Car. In 1930 The *Science and Mechanics* Journal published in its January issue an article called "Compressed Air Motor Runs Car". Roy J Meyers designed the car with four fuel tanks that will drive the car for 500 miles at a speed of 35 miles. The car had an electric heater running on a battery and generator to heat the air up 200 lbs pressure (13.79 bar). The engine resembled radial plane engine and took Mr. Meyers six years to develop. While the design was innovative, it probably could not compete with Internal Combustion "IC" engines since the articled claimed that the car would usher in a new era. Alas, it was not the case. [7]

In 2007, Motor Development International, a French Automobile company announced the MiniC.A.T. It is an air car that they have been developing for ten years. The MiniCAT is claimed to be cost efficient with one Euro per 100Km. Its mileage is from 200 to 300 miles or 10 hours of driving. They claim that once the market adapts petrol stations to fuel them, they will fill up in three minutes for a cost of almost 1.5 Euros. An alternative way to refuel is to install a small air compressor and connect it to the main. This will refill the tank in about 4 hours. Tata motors one of India's largest automobile companies signed a contract with MDI for the application of the car in the Indian market. The company believes the design to be viable. MDI introduced the OneCAT Air Car in the 2008 New York Car Show. There are videos of the cars being driven on the streets as an advertisement for the car. One of them is "Air Car - MDI - Motor Development International", and it has been published on YouTube Oct 5, 2009 by the username: HHOGASINFO. [8]

The article "Experimental Investigation on the Performance of a Compressed-Air Driven Piston Engine" did bench testing on a two-stroke compressed air engine. The engine was modefied from a four-stoke 100 cm3 internal combustion engine. The testing was done on a test bench. It tested power performance and pressure/temperature variation of the engine at pressures ranging from 5 to 9 bar. The study was performed with the engine being used as a main source of power or a supporting power system for small vehivles. Those power motors have been chosen over their electrical counterparts in hazardous environments and when contamination is to be avoided. Compressed air engines and motors are one of the better options for the environment, and this research is to determine its feasibility. Compressed air engine and motors have been used in different areas as a power motor. The issue with pneumatic motors is that they require a lot of air flow and that's why they are often operated while connected to an air compressor. Also, they have low efficiency. There are two types of pneumatic engines that are often used. They are the Vane-type and the piston-type. The Vane-type requires much more air flow than the piston type because it runs continuously. [1]

Instead of having a regular combustion engine, it is a very efficient way to opt for a pollution free pneumatic powered engine. An article published by Research-Gate discusses the alteration of a four-stoke combustion engine into a pneumatic two-stroke engine [9]. Their design talks about how a two-stroke works using compressed air from a storage source.

The compressed air enters the engine cylinder at the top dead center "TDC" once the valve opens. The pressure of the expanding gas pushes the piston down towards the bottom dead center "BDC". This is the power stroke that provides the driving power needed from an engine. This can be seen in figure 2.4. During the exhaust phase, the exhaust valve opens allowing for the expanded air in the cylinder to move out, thus pushing the piston back up towards the TDC, this can be seen in figure 2.5. Only the intake stroke is the power stroke here in this air compressed engine. So, zero pollution will be produced. [9]

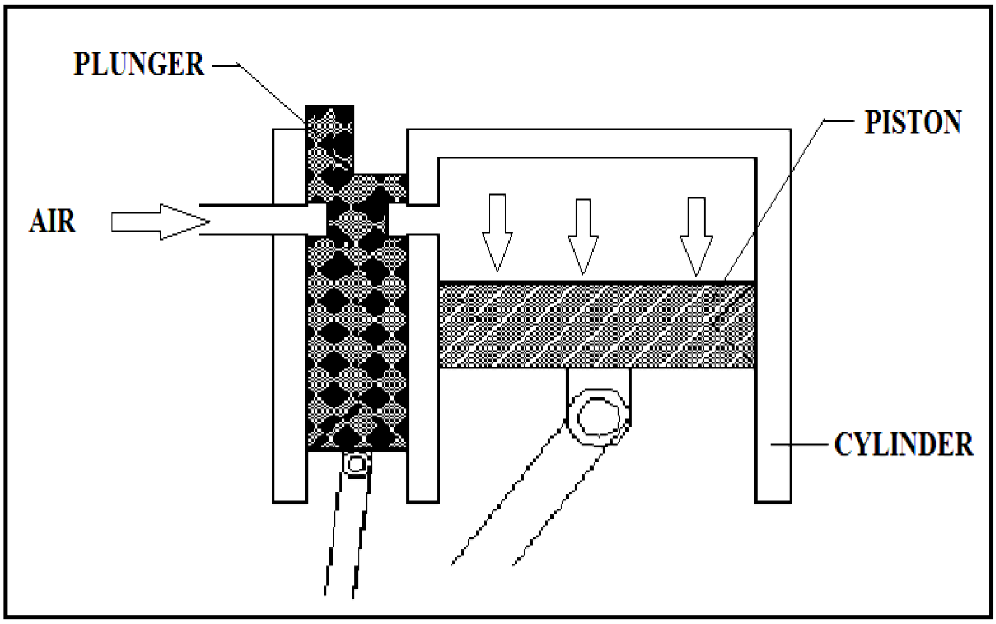


Figure 2.4 Intake Stroke [9]

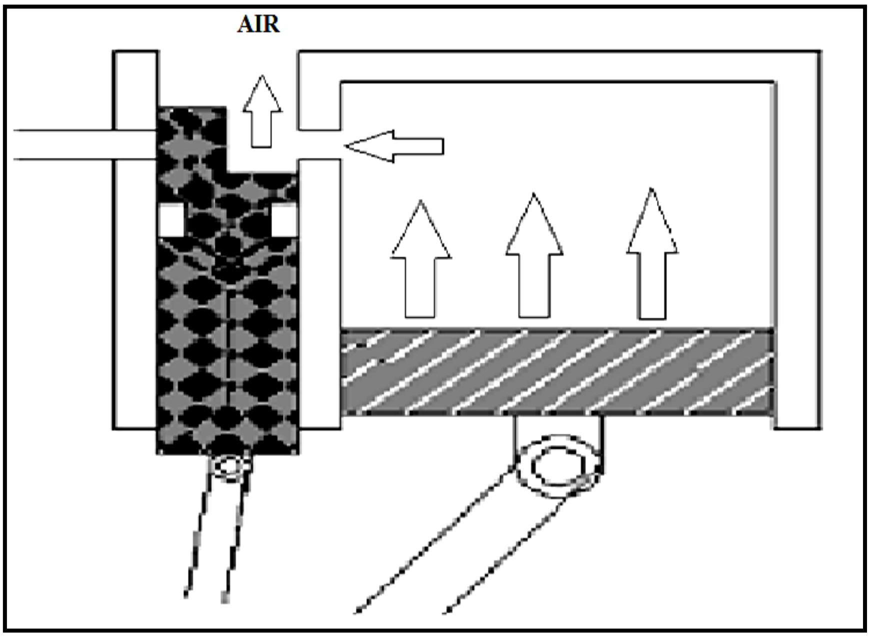


Figure 2.5 Exhaust Stroke [9]

A group of Students at a University in India, Osmania University, designed a compressed air engine. They converted a four-stroke single piston Internal Combustion Engine “ICE” of a motorcycle into a two-stroke single piston Compressed Air Engine “CAE”. They found the engine to have significantly lower power than the ICE one, but they believe that there is room for improvement. They claim that increasing the stored air pressure would improve the performance. They found the highest power output could be achieved at the starting period due to the change of pressure in the compressed air tank. The found out that CAE cost less than ICE because since there is no combustion, there is no need for spark nor carburetor. Also, fueling CAE cost less than ICE since air is abundant. [10]

Compressed air has higher pressure than the ambient atmospheric pressure. When it expands freely, it does mechanical work. A group of students from Amity school of engineering [11] have designed a compressed air engine. The main components of this design are a pressure vessel, air impact wrench, spur gear, etc.

Pressure vessels holds high pressure gases or liquids and then using valves regulates the flow. Air impact wrench uses the compressed air fed to it and gives rotary movement as an output. This uses a hammer mechanism principle where a spinning hammer strikes an anvil to make it rotate with high torque. Two spur gears are used, one having 20 teeth (pinion) and the other 40. The pinion gear is connected to the air impact wrench and when it receives torque from the wrench it transfers it to the gear which is connected to the wheels. Due to the driver gear being smaller than the driven gear, the torque increases. [11]

For the compressed air engine, air from the storage tank will be fed into it. The compressed air will expand in a chamber and work to push a piston down. A spring below the piston will be compressed and when the air escapes the chamber the spring will push the piston back up. This way the piston will start reciprocating [11]. This reciprocating piston will rotate the crank shaft. A compressed air engine can be seen in figure 2.6.

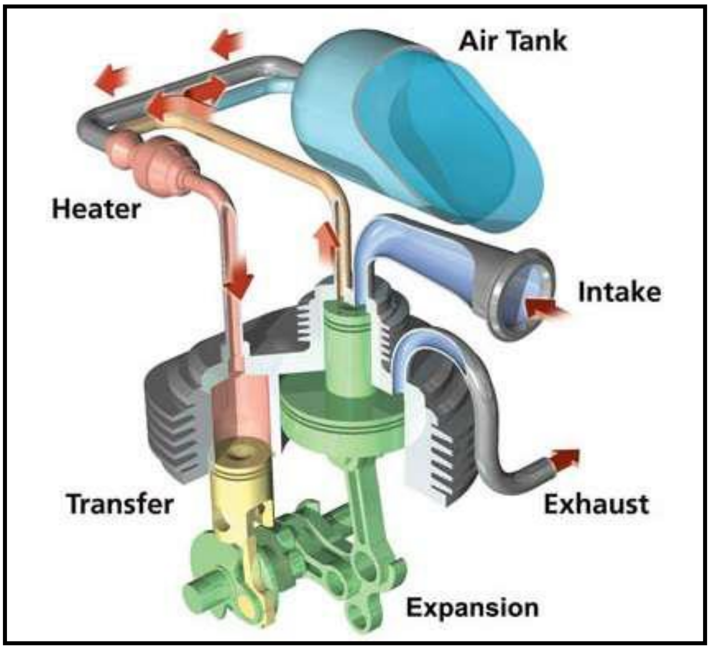


Figure 2.6 Compressed Air Engine [11]

2.2.2 Refueling mechanisms

The secondary aim of the project is to refuel the compressed air using a mechanical operation. The bicycle frame has many options by which the air can be refueled and utilized. The following design option has been used previously and has been working on air compressed bicycle models. The design option is designing a manual air pump using the pedaling power.

A mechanical device that can use the mechanical power operated by pedals as in bicycles to run an air compressor, This Approach was taken by the students of Mahakal Institute of Technology & Science, Ujjain [12]. The pedal powered air compressor set up has a simple mechanism operation with the chain and sprocket arrangement. The chain is place on the teeth of the wheel and pinion. Pedal and connecting rod are interconnected to each other with bolts. The power is transmitted through gears and this rotational power is transmitted to a rotary air pump which will refuel the air in an air tank [12]. The design can be seen in figure 2.7.

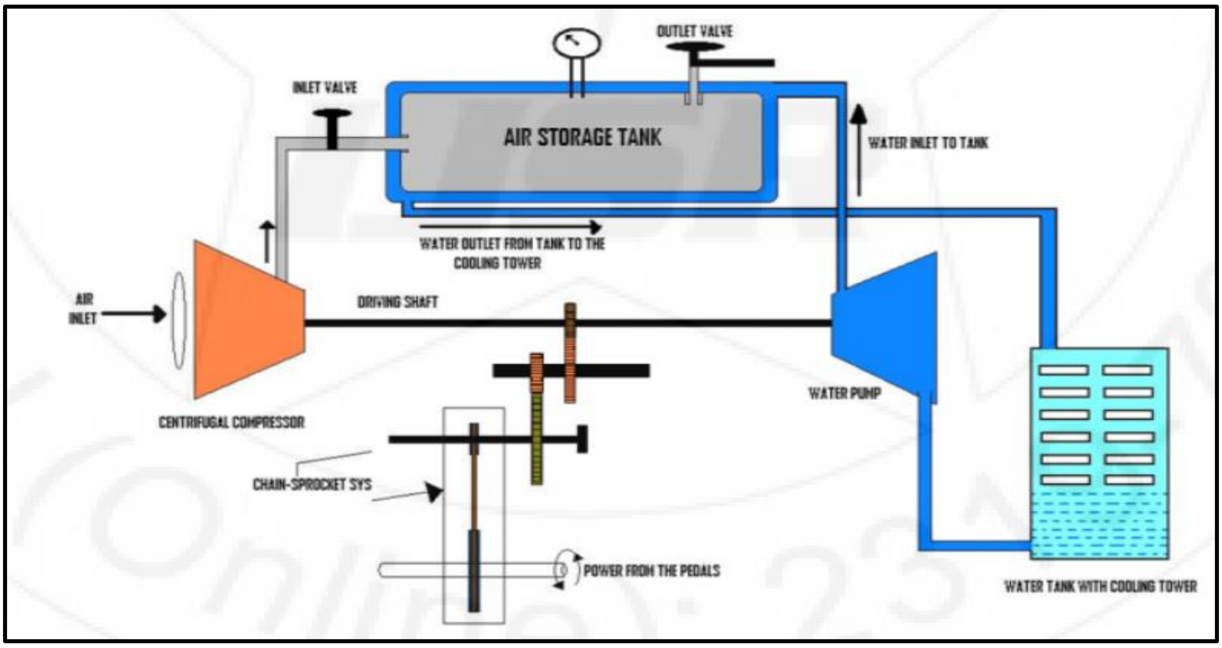


Figure 2.7 Design of a pedal operated air compressed system [12]

2.2.3 Limitations

For the air engine bicycle, there is need to know the limitations of certain components and safety. In a pneumatic powered bicycle, the use of cylinder is to generate force, and cylinders are used to generate force because they are economical and easy to install. Cylinders can also tolerate tough conditions like high humidity, dusty environments, and high pressure washing.

According to Sheila Campbell [13], Single-acting cylinders have compressed air supplied to only one side of the piston the other side vents to atmosphere. Depending on whether air is routed to the cap or rod end determines whether the rod extends or retracts. As shown in figure 2.8, Compact cylinders can be used for air engine bicycle because they take less space and where only a short stroke is required. Compact cylinder comes only in a single acting cylinder. [13]

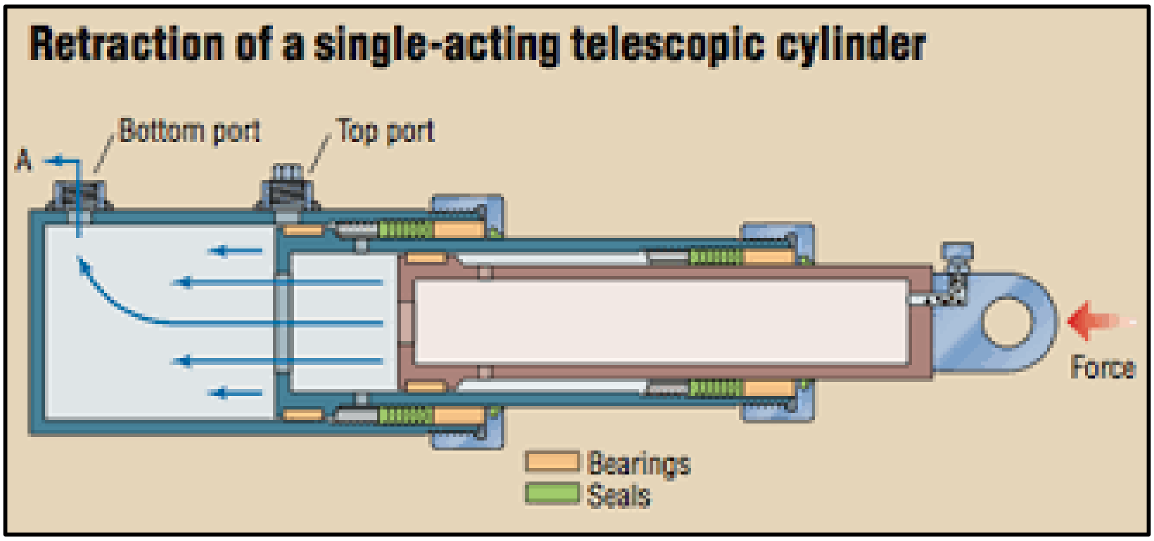


Figure 2.8 Single Acting Cylinder [13]

A research done by Motor Development International [14] discusses that refilling of a cylinder with compressed air is very time consuming when low priced or house conventional air pump is used, but if another equipment is used, like the ones used in service stations to fill the compressed air. It will take less time about ten percent of the time which low priced air pumps take.

2.2.4 Safety

According to Air Products and Chemicals Inc. [15], cylinders should not be dragged, even for short distances. They should not be dropped or struck hard. Never attempt to catch a falling cylinder. Never allow storage temperature to exceed 125°F (52°C). Cylinders cannot be exposed to corrosive materials such as ice melting compounds. Do not force cylinder valve connections that do not fit. [15]

The valve protection cap and valve seal outlet should be left in place until the cylinder has been secured in place and is ready to be used. Always use a cylinder cage or cradle to lift a cylinder. Store cylinders in a dry, cool, well ventilated, secure area protected from the weather and away from combustible materials. Always prevent sparks and flames from contacting cylinders. Always open cylinder valves slowly and carefully after the cylinder has been connected to the process. [15]

One of the important safety factors for air engine bicycle is its brakes as mentioned in the article published by International Journal of Engineering Research and Application [16], because when Compressed air boost is going to use it will gain some speed instantly and for that, if the bicycle is needed to stop in an emergency we need a hard braking system for an instant stop. For that different types of braking system can be applied but there are limitations like disc braking system is very expensive so instead of that band braking system can be used. [16]

As Zero Pollution Motors [17] mentioned in their article that these tanks get very hot when filled rapidly. If tanks are filled rapidly, then they had to sink the tanks in water to cool them. But it cannot be done with tank or cylinder on a bike, so that life of any person cannot be put on danger. Thus, it will take a longer time to fill the tank or cylinder. [17]

2.3 Comparative Study

2.3.1 Pneumatic system with actuator

Students from Santhiram Engineering College [18] worked on designing a pneumatic powered tricycle. The concept of this bike was that a pneumatic powered ratchet powered the rear wheels. This was done by using sprocket and chain drive that used the ratchets power. The design can be seen in figure 2.9. It represents the project flow chart. The components are as follows: 1. Air Cylinder, 2. Solenoid Valve, 3. Electrical Control Unit, 4. Pneumatic Actuator, 5. Power Transmitting Chain, 6. Sprocket Wheel, 7. Two Wheeler Rear Wheel.

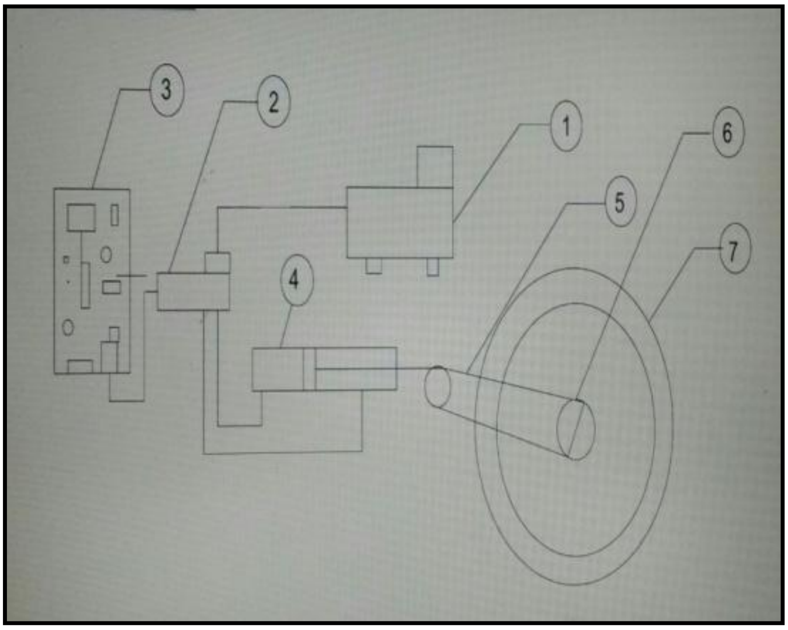


Figure 2.9 Project chart flow [18]

A sprocket wheel is a profile wheel with teeth that mesh with a chain or other similar materials [18]. It is basically a radial moving component on which a chain is passing over. In bicycles a large sprocket is driven by the pedals, which drive the chain, which then drives the rear sprocket which is connected to the wheels.

Compressed air is used to drive an actuator [18]. Actuator will use the concept of a slider crank mechanism; linear piston mechanism is geared to produce rotary movement at the sprocket. A number of sliding seals are required and the joins cause lots of leakage problems. Pneumatic pipes (hoses), made of nylon, are used to carry compressed air from the storage tank [18].

2.3.2 Pneumatic system with turbine

Another similar work was done by students of Nehru College of engineering [19]. The idea that they used was of using a turbine to pneumatically power their bicycle. The pressurized air enters the turbine and expands, moving the vanes, and thus creating mechanical work by rotating the shaft. This shaft is coupled directly with the rear wheel. The components used by them were an air turbine, compressed air tank, connectors, ball valves, and a supporting frame. The working model can be seen in figure 2.10 below.

Figure 2.10 Working model of turbine powered bike [19]

Air turbine is the most important part of their project. It is a vane type air turbine which can be seen in figure 2.11. It is proposed to work in reverse of the working principle of vane type compressors [19]. The turbine consists of 4 vanes which are made of Teflon, which is high in strength and has less wear resistance. The turbine shaft is coupled to the rear wheel using key arrangement. The air turbine has a capability to yield an output of 5 horsepower at 6 bar air pressure and for a speed of 2000-3000 rpm.

The working principle is that the compressed air is stored in the tank. This high pressure air is allowed to go into the turbine with the help of valves which are controlled from the accelerator. The high pressure air expands inside the turbine, producing a rotational torque which rotates the rotor, which in turn rotates the shaft coupled to it. This is how pneumatic energy is used to drive the bicycle. [19]

2.3.3 Mechanism of refueling the air

Joao and Eduardo [20] designed a pneumatic regenerative break system for large vehicles. It was used to refuel the compressed air using energy from the brakes. The proposed design of the pneumatic brake was installed in parallel with the traditional brake. It consisted of a compressor, a pressure vessel, and a clutch that linked transmission with the compressor. The compressor selected was a double action piston-type compressor. The design of the regenerative brake system applied on a long vehicle can be seen in figure 2.10.

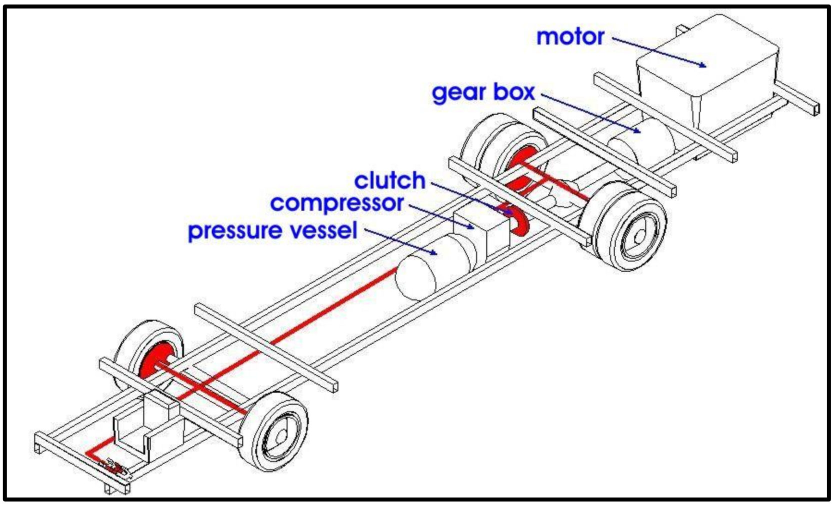


Figure 2.11 Proposed regenerative system for a bus [20]

As the brakes are pressed, the transmission system disconnects the motor of the transmission train. Then, using the clutch, the compressor is coupled to the transmission axis. This way the reverse process is initiated and the compressor starts sending air to the storage tank. Both the traditional brakes and the regenerative work together at the same time. [20]

A similar work was carried out on a bicycle in India [21]. The design consisted of a compressor coupler assembly. Which consisted of a compressor, frame, coupler, coupling and supports. Coupler and compressor are bolted to the supports; a coupling is used to connect the coupler with the compressor. This assembly is fixed to the frame of the bicycle where it is possible for a motion by a circular member such as sprocket. This works as instead of the braking, the coupler is engaged to slow down the bicycle. Through this the power gets taken up by the coupler which then transfers it to the compressor. This power is then used to regenerate the compressed air. This assembly can be seen in figure 2.11.

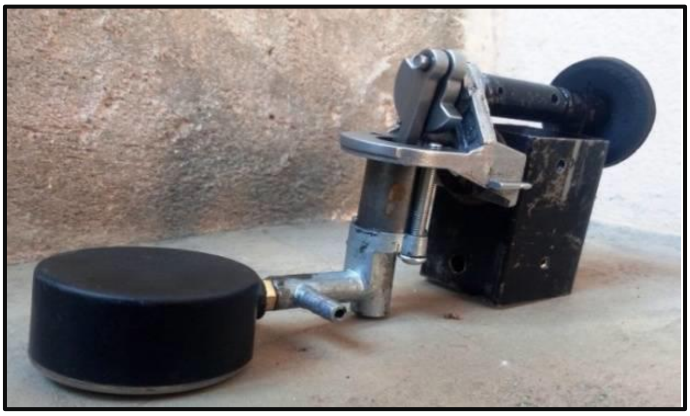


Figure 2.12 Compressor coupler assembly [21]

The compressed air is transported through hoses to the tank. The circuit of the hoses contains four valves; Non return valve, pressure relief valve, a bicycle tire valve, and a control valve. The working design here is that the non-return valve passes the compressed air into the receiver, the pressure relief valve limits the maximum pressure for safety purposes and integrity of the assembly, the bicycle tire valve allows for external air to be taken in for filling, and the control valve simply controls the flow to the air engine. [21]

Another project was done to refuel the compressed air using Electric Powered Air compressor. This Approach was taken by the students of Gnanamani College of Technology, India [22]. The main components involved in this project consist of engine, battery, compressor unit, spur gear arrangement and linkages. All components are mounted on the frame called base frame. Here compressor unit is placed at the rear side of the vehicle. 12 Volt DC compressors are used to compress the air. [22]

2.3.4 Distinction of our work

Our project is going to be different from the work described in the previous sections. We are going to be using a small one cylinder engine as the source of our work which will be run using pneumatic power. Modifications will be done to the engine so that it is capable of running with pressurized air as its fuel. Our project will not be pursuing the refueling mechanism due to its complexity. We believe that a refueling mechanism is a complete final year project in itself. So, we will be addressing the refueling mechanism in our future recommendation in the final chapter of this report.

Chapter 3: System Design

The design of the pneumatic powered bicycle follows very basic engineering principles. This chapter will solely focus on the design components of the pneumatic powered bicycle. Key points will be addressed in detail, such as the design constraints, the engineering standards followed, theory and calculations applied, and the implementation techniques. Figure 3.1 below shows the basic design of the system. The components labeled are:

1. One cylinder engine
2. Engine sprocket
3. Pneumatic hoses
4. Air cylinder
5. Regulator

Figure 3.1 Concept Design

3.1 Design Constraints and design methodology

The concept of pneumatic powered bicycle can be used in the whole world because it is environmental friendly as compared to other combustion engines, and it is cheaper as compared to other fuel consuming vehicles. However Pneumatic powered bicycles have some restrictions which can affect the overall design and performance.

3.1.1 Geometrical Constraints

One of the main geometrical constraint is cylinder of compressed air which weight around 8 kg. The average human body weight is around 80 kg. the overall weight of the cycle, valves, and engine, will be 105 kg. In this design, if another air cylinder is added for more boost than the weight of the bicycle will increase, for which everything has to be changed according to the weight.

3.1.2 Sustainability

A pneumatic powered bicycle is more economical than fuel-powered cars, motorcycles and way cheaper than electric bicycle. Depending on the person's physical condition, the type of terrain or the distance, the pneumatic powered bicycle can be more comfortable since it allows the rider to cover more distance or climb hills. The bicycle does not do the riding for you, it provides a slight impulse when you start off or ride uphill with a smooth movement.

3.1.3 Environmental

Environment is one of the main factor that must be taken into consideration while designing any project. The environment can affect the efficiency of the project. Due to the hot weather of Saudi Arabia, the tires of thebike will wear out sooner than expected. There would be more mechanical losses in the system and the output power will be lower than calculated. Due to hot weather, this project will not be that successful in Saudi Arabia as compared to Europe or other countries, because of fewer bikers in Kingdom. The air powered bicycle is environment friendly, noise free bicycle as compared to other motorcycles which have high noise pollution.

3.1.4 Economic

While designing a project economy must be kept in mind as it is one of the constraint. If people cannot purchase or maintain air powered bicycle because of high cost then it is not consumer friendly. In Saudi Arabia, prices are very high as compared to other countries because of shipment and less manufacturing industries. A small 50cc engine costs 1000-1500 riyal in Al-Khobar, while the same engine is around 500-800 riyal in Riyadh, and it is, even more, cheaper in Pakistan around 200 riyals. This kind of economic constraints put alot of pressure on students as they have no source of income. Overall our project is consumer friendly as it doesn’t need expensive fuel to operate. Fuel prices are very high around the world,the consumer is looking for cheap transportation and in pneumatic powered bicycle only compressed air is needed which is way cheaper than fossil fuels.

3.1.5 Manufacturability

Air powered bicycle can be manufactured in any mechanical workshop. The main constraints in a manufacturing air powered bicycle are assembling of an air cylinder with theengine, due to less space available. The most important constraint of the air powered bicycle is a modification of valves camshaft which is very important, for that only few turning workshops were available. As mentioned above it can be manufactured at any place with some important mechanical tools. Workshop owners take alot of money for allowing us to work in their shops.

3.1.6 Safety

Safety plays a very important role when it comes to constraints. A rider must always wear a helmet and knee pads as well. A ride should make sure that the helmet he is wearing is of good quality and is good for safety purposes. Incase if he is involved in an accident, chance of injuries will be minimum.

3.2 Engineering Standards

The Engineering standards which are taken into consideration are as follows:

1. ISO 4210:2014 standard for bicycles

The International organization for standardization (ISO) has published this standard so that the bicycles manufactured are in compliance with this International Standard and will be as safe as possible. This standard sets certain rules and regulations on the bike frame, the bike steering, bike wheel and forks. Different testing methods are used to see that whether the manufacturer has met these standards. So the bike which we will be using is ISO 4210:2014 certified and hence it is safe.

2. ASME BPVC Section VIII-Division 1

This standard is used by American society of Mechanical engineers, this standard is used for manufacturing small pressure vessels and heat exchanger devices. The purpose of this standard is to make the pressure vessel as safe as possible and also set different criteria which a manufacturer should follow so that the quality can be same throughout the world.

3. ISO 3857-2:1977

The International organization for standardization (ISO) has published this standard to establish term and conditions in English and in French relating to compressors. This standard comprises of temperatures, flow rates, pressures, powers, specific energy requirement, efficiencies and related information.

4. Valves standard’s provided by Swagelok

These standards are provided by the vendor so that the consumers can utilize the important information about the valve such as maximum operating pressure and temperature and its size specifications. We have chosen to buy Swagelok valves because they have used ASME standard in making these quality products.

5. StVZO standard

This is a German bike safety standards which is followed by most of the bikers around the world. The purpose of this standard is to make biking a safer commute. According to this standard the bike should always have a white led at the front, the rider should always wear helmet while riding it and the bike should have a taillight and reflectors so that it is clearly visible in all lighting conditions.

3.3 Theory and theoretical calculations

The engine was designed to give a boost for a bicycle in motion. Therefore, we used Newton's second law of motion to find the force needed to keep the bicycle in motion in an uphill. This force has to be almost doubled to give a sufficient boost in an uphill. The parameters which we have chosen are: the total weight acting on the system, and the drag force of the air. A general diagram for the acting forces on the bicycle can be seen in figure 3.2 below.

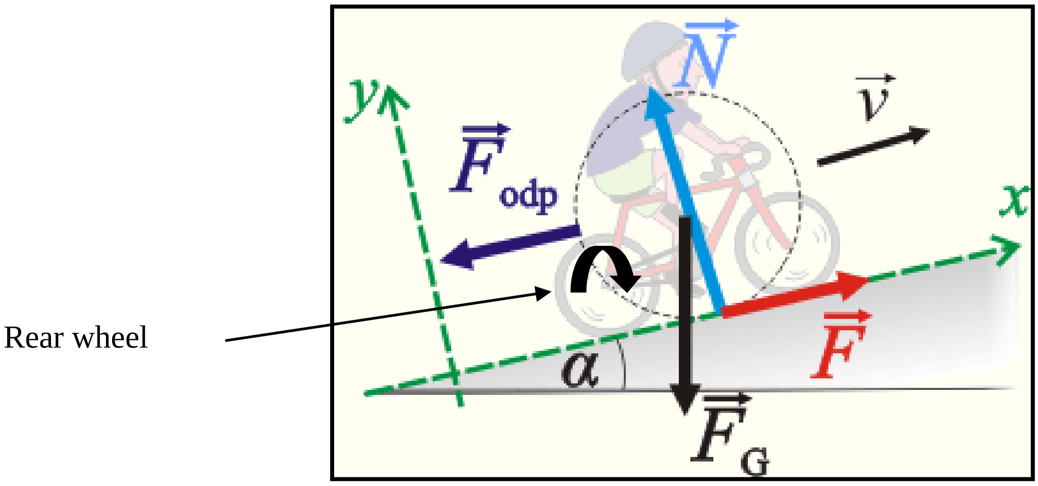


Figure 3.2 Force Diagram

The formulas used as the basis of calculations can be seen in table 3.1 below.

Table 3.1 General Equations

	Equation
$Weight = mg$	1
$Force = F_{drag} + Wsin\alpha$	2
$Torque = Fr$	3
$A = \pi r^2$	5
$Pressure = FA$	6

m: mass

g: gravity

F_{drag}: drag force

α: the incline angle

A: area of the piston's surface

Using the formulas listed in table 3.1, and using the scenario as described in the first paragraph, The outcome of the calculations is as follows:

The force required to keep the bicycle in constant motion is **F = 513.47N**

The torque of the rear wheel is **T = 154.041 Nm**

The torque of the small sprocket attached to the rear wheel is **T = 25.67 Nm**

Thus, the piston should deliver a force to the crank which should be greater than the force required to generate a torque of 25.67 Nm at the small sprocket. Similarly, the pressure from the air tank should be accordingly enough to generate the desired force at the piston. The diameter of the piston of the engine is about 0.05 meters. so using this and the minimum force required (513.47 N), the required pressure to push the piston down and working would be **P = 2.61 bar**

The first law of thermodynamics states that in a closed system the change of energy is equal the heat supplied to the system minus the work done by the system. Delta U = Q-W. Our pneumatic engine doesn’t consume heat it only produces work based on the rotation of its shaft, which is caused by the movement of the piston. The energy of the system is reduced to w=PV. The volume is 0.0002 m3. The pressure is 10 bar. This means the engine will produce 200.119 J in one inlet stroke. The engine has two inlet strokes each cycle, so the work is about 400 J in a full round of the shaft. The power 0.078 Watts each round of the shaft.

These calculated parameters are the minimum requirements for the mechanism to work.

3.4 Product subsystems and selection of components

The subsystems required are a single cylinder engine, air tank, extra drive chain, multiple sprockets, and hoses. The minimum requirements of force and pressure were found out in the previous section. And according to the availability of the products from the local or international market, the components were selected.

3.4.1 Engine

The main component of the project is the engine and the selected one is a four stroke 50cc internal combustion engine used in a small generator. A lot of parts were removed as they were not required such as the fuel tank, carburetor, air filter, etc. further modifications will be done to adjust the engine according to the requirement of the project. The selected engine can be seen in figure 3.4 below.

Figure 3.3 50cc Engine

3.4.2 Camshaft

The camshaft of the engine is the most important part of this project. The original camshaft that comes with the engine is a 4-stroke camshaft. In order for the engine to operate with pressurized air, a 2-stroke camshaft will be required. Thus, modification to the original camshaft will be required. A 2-stroke camshaft can be seen in figure 3.5 below.

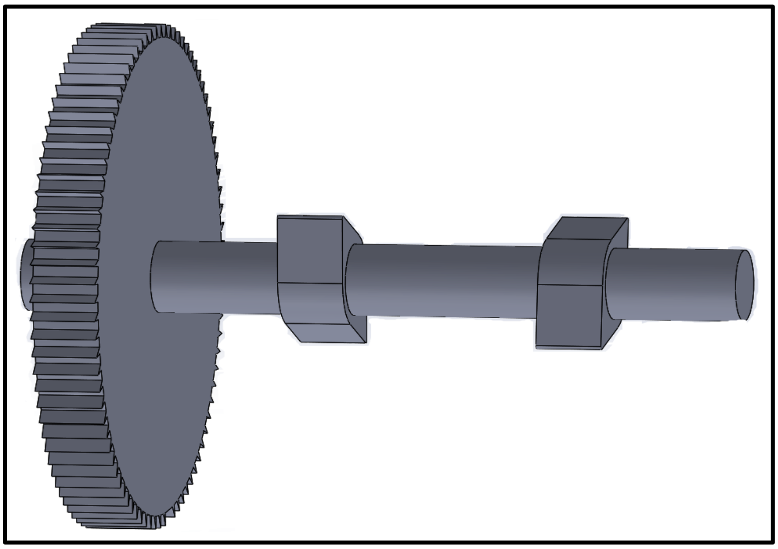


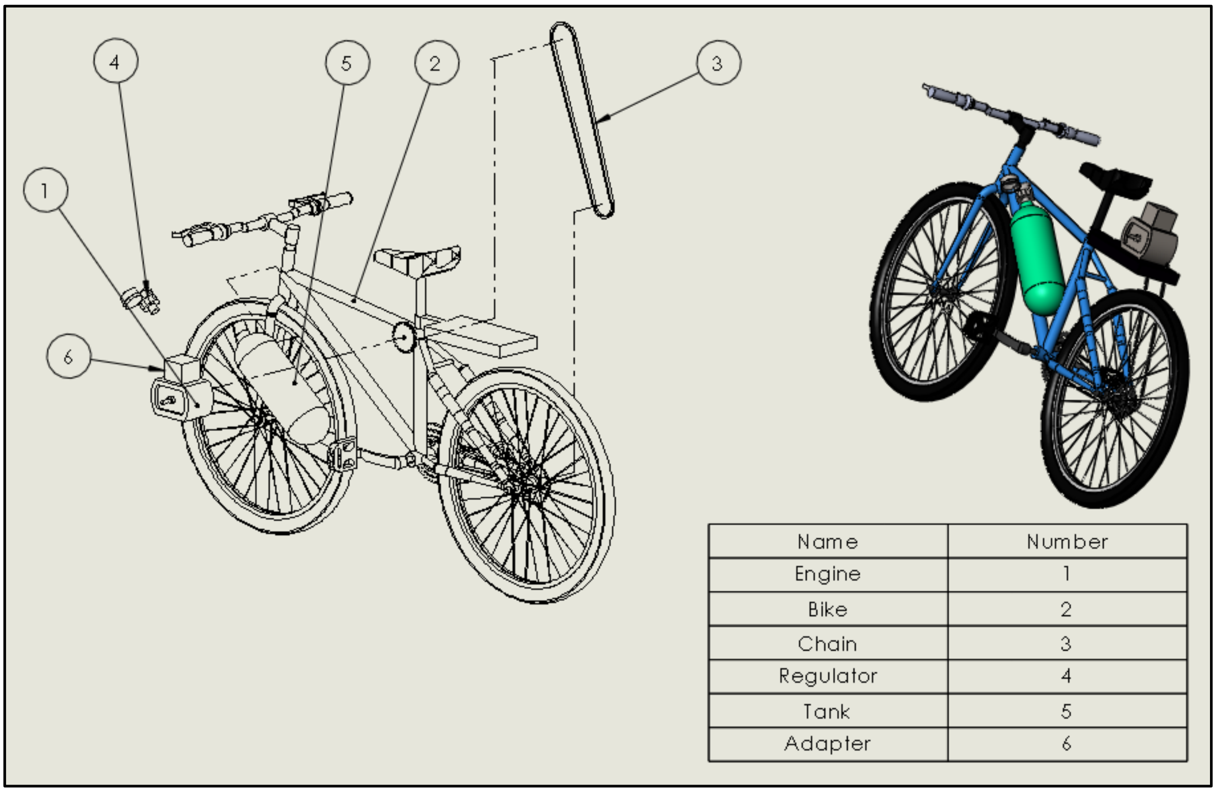
Figure 3.3 2-stroke camshaft

3.4.3 Cylinder and hose

A cylinder was selected according to the pressure needs. Taking losses into consideration, a high capacity cylinder was selected. The cylinder can be seen in figure 3.5 below. Furthermore pneumatic hoses were selected for the transportation of the compressed air from the cylinder to the engine. These can be seen in figure 3.6.

Figure 3.4 Pneumatic hose and air cylinder

3.4.4 Bicycle CAD



Name	Number
Engine	1
Bike	2
Chain	3
Regulator	4
Tank	5
Adapter	6

Figure 3.5 CAD of the Bicycle with the Pneumatic Burst System

3.5 Implementation/Assembly of design

3.5.1 Engine

We will be using a 5 HP generator engine (Robin EY-20), which can be seen in figures 3.6 and 3.7. The engine is the main component of the project. The engine can produce a maximum of 5 HP per 4000rpm with a torque of 9.3 N.m per 2800 rpm. All the other components like fuel tank, carburetor and the cover were removed from the generator. The engine will be attached to a base with clamp and bolts and will be connected to the compressed air cylinder with the help of hoses.

Figure 3.6 Robin EY-20 Generator before disassembly

Figure 3.7 Robin EY-20 engine

3.5.2 Adapter

An adapter was designed using solid works and will be manufactured. This adapter will be attached to the throttle body. As the carburetor was removed from the generator engine, this adapter will be used as a connector to connect the pipe to the valve. A one way valve will be fitted into this adapter. This can be seen in figure 3.8.

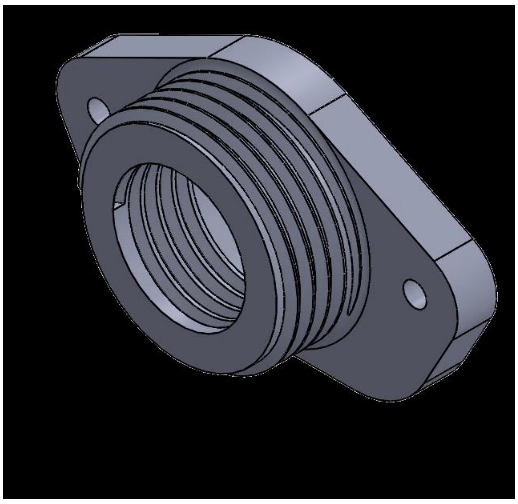


Figure 3.8 Adapter made using solidworks

3.5.3 Air cylinder, Regulator and Hoses

A compressed air cylinder will be used to provide the desired air to run the engine. This tank is a compressed air storage vessel, which is held under pressure. The cylinder can be seen in figure 3.9 below.

Figure 3.9 Compressed air cylinder

We will be using a 2 meter long pneumatic hose for the flow of air from cylinder to the engine. One side of the hose will be connected to the regulator and the other side will be connected to the check valve. The basic function of this pneumatic tubing or hose is to convey pressurized air to the valve. A pressure regulator will be used to match the flow of gas through the regulator to the demand for gas placed upon it, whilst maintaining a constant output pressure. Both of these can be seen in figures 3.10 and 3.11 below.

Figure 3.10 Pneumatic Hose

Figure 3.11 Regulator connected to Pneumatic Hose

3.5.4 Cam

The cam of the engine will be modified from 4 stroke cam to 2 stroke cam. A steel piece will be welded to the shaft of the cam and then it grinding will be done for the finishing. Cam of a four stroke can be seen in figure 3.12 below and the two stroke can be seen in figure 3.13.

Figure 3.12 original cam of the engine

Figure 3.13 Modified cam of the engine

3.5.5 Engine and tank carrier

The bicycle rear carrier was removed and a new carrier was welded as per the engine dimensions. The dimension of the carrier was chosen carefully so that it will be easy for the users to remove the engine whenever they want. The stand can be seen in figure 3.14.

Figure 3.14 Bicycle carrier without engine

The figure 3.15 below shows the carrier with the engine fitted.

Figure 3.15 Bicycle carrier without engine

Two clamps as per the size of the tank were welded next to the saddle. These clamps can be fastened with the help of nut and bolt, hence making it easy for the user to change the tank whenever required. This can be seen in figure 3.16.

Figure 3.16 tank carrier

3.5.6 Sprocket and Key

A key was made and attached to the sprocket using welding. This key was manufactured according to the shaft size of engine. This key was also detachable, in case any modification needs to be done to the engine. This can be seen in figure 3.17.

Figure 3.17 Sprocket welded to the key

Chapter 4: System Testing and Analysis

This chapter includes the experimentation of the pneumatic powered system. It includes details about the tools used to test the system, how the setup was done, and what data was acquired. Lastly, the results are presented at the end of this chapter.

4.1 Experimental Setup, Sensors and data acquisition system

The first test was done to find out the impact the pneumatic powered engine would make while riding a bicycle. For this, the testing was done in a running track around the football field. Timing was recorded for the ride time over a 50 meters track. Testing was done twice, first with normal cycling and second with the engine running. The setup can be seen in figure 4.2.

Figure 4.1 Impact test setup

Experimentation was done to find out the rpm that the bicycle achieved with and without the engine running. To do this the bicycle was rode in a straight line from a starting point to a finish point. Video cameras were used to film both trials and a stopwatch was used to measure the time it took for both runs. The third experiment conducted was to find out the rpm the rear wheel achieved. This was done by holding the cycle up from the rear and testing the rpm. This setup can be seen in the figure 4.1 below.

Figure 4.2 Testing setup

The main component in the prototype is the engine shaft rotation to produce power and transfer then to the pedals of the bicycle. Where the torque produced will contribute to reducing pedaling efforts. The objective of this test is to ensure that the engine is working perfectly as per the design calculations. A digital tachometer was used to measure the rotation speed of the shaft. This device displays the revolutions per minute (RPM) on the screen. The tachometer can be seen in figure 4.3.

Figure 4.3 Tachometer

The tachometers features are listed below

- Rotation speed display is five-digit LCD number with maximum of 99999.
- Display 0 below 50RPMM.
- Measuring distance is 50mm--250mm (when the battery voltage is sufficient).
- Display voltage lower than 4.5V when batteries are low.
- Dimension: 155*60*27 mm
- Weight: 120g
- Power supply: 4*1.5V SIZE AAA battery
- Auto off time is 30 sec.
- Product size: 170mm*60mm*27mm / 6.1"*2.4"*1.1
- Product weight: 120g
- Safety rating: CE RoHS

further specs about the accuracy can be seen in table 4.1 below.

Table 4.1 Tachometer accuracy table

Range	Resolution	Accuracy
50~99.99 RPM	0.01 RPM	±(0.03%+2)
100~9999.9 RPM	0.1 RPM	±(0.03%+2)
10000~99999 RPM	1 RPM	±(0.03%+2)

4.2 Results, Analysis and Discussion

The first test was done to find out how much impact the engine made while cycling. After taking similar runs and recording the time, we found out that the rider took 16 seconds to cover 50 meters. On the other hand, while running the engine at 6 bars pressure, the rider took almost 12 seconds to complete the 50 meters. So for a 50 meter distance the engine was able to provide a boost that reduced time by 4 seconds and also reduced the efforts the rider needed to cycle.

The second test was conducted to find out how long the air cylinder can be used for at certain pressures. According to our calculations, we opted for a 10 bar pressure to run the engine. So, we tested for several operational pressures and came up with results that can be seen in table 4.1 below. The pressure range was limited by the capability of the air regulator and that is why the test was conducted for the selected pressures. As seen in the table, the total time is the limit of the air cylinder at certain pressures. The rider can use as many boosts as they desire that cumulate up to the total time.

Table 4.2 Operation time at selected pressures

Pressure (bar)	Time (seconds)
8	70
10	55
12	42
14	25

After carrying out the rpm experiment, it was pretty obvious that the engine provided a boost for the rider. From the filming and time recording for the experiment it was found out that for a distance of about 50 meters, the rider was able to complete the track 2 seconds earlier than they did without running the engine.

The second test was done to find RPM. The main goal of the project is to provide a boost to ease the ride. This boost can be observed through the bikes velocity. RPM is a good indication to how much velocity we will get since we can find linear velocity from RPM and the wheel’s radius. The shaft rotates to produce power and transfer that power to the wheels of the bicycle. Where the torque produced will provide the rider with a boost. The objective of this test is to ensure that the engine is working as per the design objective and calculations.

A digital tachometer was used to measure the rotation speed of the wheel. When the engine was off, the RPM was 688.9, see figure 4.3. After turning the engine on, the RPM got up to 1890.5 RPM, see figure 4.4. This reading was achieved when we had an air pressure of 5 bars supplied to the engine. This correlates to an increase by a factor of 2.74 for the RPM. To visualize the increase of RPM we did another test.

Figure 4.4 rpm of wheel without engine running

Figure 4.5 rpm of wheel with engine running with 5 bar

Figure 4.4 and figure 4.5 show the RPM reading of the rear wheel when the engine is off and when the engine is on respectively. The test was to see how fast the bike will finish a 50 m distance with and without the engine

Chapter 5: Project Management

Due to a restricted time period, the project required a strict management in order to achieve success. An initial plan was laid out, tasks were assigned carefully, challenges were faced, budgeting was done, etc. All of the project management is expressed in detail section wise below.

5.1 Project Plan

Table 5.1 Gantt chart table

Tasks	Start Date	Days to complete
INITIATION	2/14/2018	3
Kick off meeting		
Gantt Chart	1/31/2018	5
Project Definition	2/5/2018	4
Project Objectives	2/3/2018	1
Project Specification	4/16/2018	1
Application	2/4/2018	1
PLANNING	2/5/2018	2
Literature review	2/7/2018	3
Project Background and History	2/10/2018	10
Previous Work	2/10/2018	10
Comparative Study	2/10/2018	10
Parts	2/15/2018	10
SYSTEMDESIGN		
Design Constraints	3/1/2018	14
Design Methodology	3/1/2018	14
Components	3/5/2018	14

Implementation	3/5/2018	20
SYSTEM TESTING ANALYSIS		
Subsystem1	4/1/2018	18
Subsystem2	4/1/2018	18
Results	4/18/2018	1
Discussion	4/18/2018	3
PROJECT MANAGEMENT		
Project Plan	1/31/2018	2
Contribution of Team Members	1/31/2018	93
Project Execution Monitoring	1/31/2018	93
Project Bill of Materials and Budget	3/5/2018	45
PROJECT ANALYSIS	4/1/2018	33
Life Long Learning	3/25/2018	5
Impact of Engineering Solutions	4/1/2018	5
Contemporary Issues Addressed	4/1/2018	5
CONCLUSION & RECOMMENDATIONS		
Conclusions	4/20/2018	5
Future Recommendations	4/20/2018	5
REFERENCES		

5.2 Contribution of Team Members

The completion of the project required multiple tasks to be accomplished. Tasks regarding the project report, prototype, presentations, etc. All of the tasks were carefully analyzed and distributed to the team members according to their strengths. Various tasks and the contributions made can be seen in detail in table 5.2.

Table 5.2 Tasks and contributions

No.	Tasks		Assigned	Contribution
1	Abstract & Acknowledgement		Abdulelah	40.00%
			Sohaib	40.00%
			Salman	20.00%
2	Gantt Chart		Abdullah	50.00%
			Abdulelah	50.00%
3	Report Format		Sohaib	100.00%
4	Project Introduction	Definition	Faraaz	30.00%
		Objectives & applications	Salman	30.00%
		Specifications	Sohaib	20.00%
			Abdulelah	20.00%
5	Literature Review	Pneumatic Background	Abdulelah	20.00%
		Theory about air compressed systems	Salman	20.00%
		Design of pneumatic systems	Sohaib	20.00%
		Safety for pneumatic bicycles	Abdullah	20.00%
		Refueling mechanism for compressed air	Faraaz	20.00%
6	Design	Design of the pneumatic system & calculations	Sohaib	20.00%
			Abdulelah	20.00%
		Constraints of the system	Abdullah	20.00%
		Standards needed	Faraaz	20.00%
		Implementation Method	Salman	20.00%
7	Project Budgeting		Faraaz	100.00%
8	Material Survey	Engine	Sohaib	20.00%
			Abdullah	20.00%
		Cylinder, pipe, & regulator	Sohaib	20.00%
			Salman	20.00%
		Valves	Abdullah	20.00%
9	Manufacturing	Adapter solid works model for manufacturing	Abdulelah	50.00%
		Cam modification design	Abdullah	25.00%
			Sohaib	25.00%
10	Testing		All members	100.00%
11	Presentations	Content & Delivery	All members	50.00%
		Format	Sohaib	50.00%

5.3 Project Execution Monitoring

The main purpose of project execution is to progress and produce the project's expected deliverables that must be carried out on time and within budget and must meet the agreed upon scope and accomplish the quality requirements. From the very first day of the project we made a group on WhatsApp, as this is the most convenient tool to communicate and distribute the tasks, share the ideas and keep ourselves up to date with the project. Another tool used for the project monitoring was Google drive, all our project work was uploaded online on the drive so that we can share and work on the same documents without having conflicts. As this project has several activities, they can be seen in table 5.3 below.

Table 5.3 Table of activities

Time	Activities
Once a week	Learning Assessment class
Daily meeting	With the group members
Weekly meeting	With the advisor
Tue, April 3	Mid-term presentation
Tue , April 3- Sat, April 14	Testing and modifications
Thu, May 3	Final presentation

5.4 Challenges and Decision Making

The project progressed smoothly with minor difficulties with procurement of materials until we reached the assembly phase where we faced two challenges. The first was with air leaking out of the system. The second was with the piston getting stock at the bottom dead center. The following is an explanation of each of challenges and how we dealt with them.

The leakages were in one area of the engine. Initially a part of the intake and exhaust group was kept because it was thought to be necessary for regulating the engine. In figure, the highlighted part of the group had almost all of the leakages, and the governor group was mounted on it. To fix this problem the part was taken out and the adapter was installed onto the engine in its place, and the cam-shaft was modified.

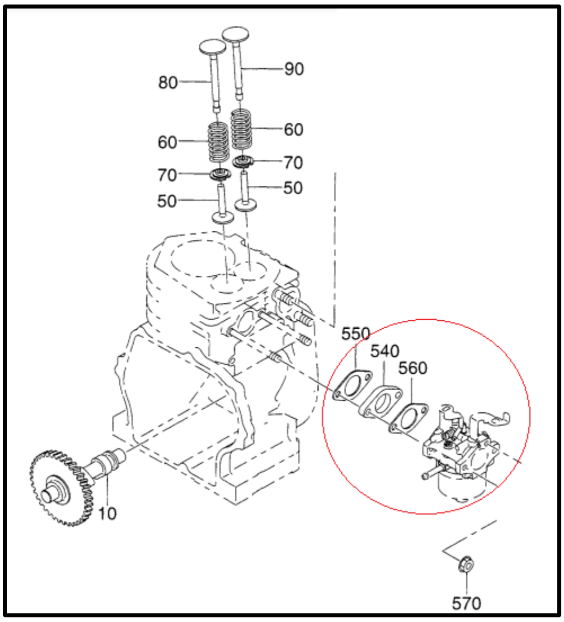


Figure 5.1 Parts originally kept of the intake/exhaust group

The piston being stuck challenge had to be caused by the cam shaft. Since the engine was going to have pressurized air as its source of power, the engine's cycle has changed. In internal combustion engines there are two strokes were neither the intake or exhaust valves are open. They are meant to compress the fuel and combust it. Those strokes were achieved by having the cam shaft dwell at the minimum height for almost half the cycle time, or as we liked to think about it two quarters. However, those two strokes are not needed in a pneumatic engine. We thought of two viable ideas to fix this problem. The first was modifying the cam-shaft to perform two pneumatic cycles in the time took for one IC cycle. The second was ceiling the existing inlet and exit and modify the engine's top to have one opening and connect a mechanism on it to allow for an intake and exhaust of air. However, this approach will require us to build a mechanism to transfer the motion of the engine's shaft to the mechanism on top to correlate the intake and exhaust with the piston's movement. We went with the first approach as it required less manufacturing and modifications, and most importantly it was easier to try. The cam shaft has two cams one for intake and another for exhaust. In IC the each cam dwell at the maximum height once to allow for one intake and one exhaust, so we added to each cam another maximum dwelling period at 180 degrees of the original one.

5.5 Project Bill of Materials and Budget

At the beginning of the project we have estimated that around SAR 1000.00 will be the total cost of our project. The reason why we have chosen this estimate is because the main component required for the project, which is the bike, was available to us at no cost and our direct cost in the project was the Engine and check valve. The total cost in this project was a little higher than our estimate which is around SAR 1120. The following table 5.4 will show the detail of our spending.

Table 5.4 Bill of materials

No.	Item Purchased	Amount
1	Folder	**SAR 0.00**
2	Bike	**SAR 0.00**
3	Engine	SAR 400.00
4	Air Tank	SAR 180.00
5	Cleaning	SAR 30.00
6	Regulator	SAR 90.00
7	Pipe	SAR 25.00
8	Inlet Adapter	SAR 150.00
9	Cylinder Refills	SAR 170.00
10	Engine mod	SAR 50.00
11	Adapter Holes	SAR 20.00
12	Modified Cam	SAR 120.00
13	Cycle sprocket	SAR 25.00
14	Bike stand for engine	SAR 320.00
15	Sprocket Adapter	SAR 120.00
16	Exhaust adapter	SAR 50.00
17	Report print	SAR 19.00

18	Sprockets	SAR 50.00
19	Additional cost	SAR 210.00
20	Paints	SAR 10.00
21	Sprocket adapter and welding	SAR 100.00
22	bicycle shop	SAR 80.00
23	Sprocket welding	SAR 20.00
24	Engine stand alteration	SAR 60.00
25	Cycle chains	SAR 50.00
26	Safety cover	SAR 200.00
27	Brochures	SAR 80.00
	Total	SAR 2,629.00

Chapter 6: Project Analysis

In this chapter, we are going to discuss the analysis we have done for our project. The experiences that we have learned from, the impact that the project has made, and the issues that the project has addressed.

6.1 Life-long Learning

Doing projects is a lifelong learning process as it brings various experiences. Throughout our project journey we have learned many things such as time management, keeping up with the deadlines, brainstorming sessions, effectively using software's, and teamwork. These things helped us to successfully complete the project. All of the mentioned things are explained in a detailed manner below.

6.1.1 Time management

One of the most important skills required to complete this project was the time management skill. All the objectives and goals had a specific deadline and with proper time management we were able to achieve our goals. All the tasks were equally distributed amongst the team members and completed on a specified time. To keep up with the time we developed a Gantt chart and kept updating it day by day. It is one of the best techniques to complete all the work within time and have a record of it as well.

6.1.2 Brainstorming Sessions

Brainstorming improved our critical thinking and problem solving skills as a team. All the members felt more open to throw different ideas and seek advice on the project. Brainstorming sessions provided each team member a free and open environment that encouraged everyone to participate. Also, it helped all the team members to feel that they have contributed to the solution. These sessions helped us to understand the importance of group ideas and how a problem can be solved if all the team members share their opinion and solutions.

6.1.3 Software's and technology

Throughout the project we have used software's such as Solid Works, Microsoft excel, Microsoft word etc. All these tools were used to complete the project successfully. For example, Solid Works was used for making various parts of the project, Microsoft word was used to make drafts and the final report, excel was used to make Gantt chart and various tables. Using these software's not only help us to complete the project but also in our professional life they will be valuable as they are a part of lifelong learning process.

6.2 Impact of Engineering Solutions

Our project has a great impact on the environment, society, andeconomics. Below are some details of the impact of our project.

6.2.1 Environment

Our project has a great impact on the environment. Air engine bicycle contributes to clean environment. Air engine bike significantly reduces transportation emissions while also reducing traffic congestion and the need for petroleum. The total number of pounds of pollutants, comprised of hydrocarbons, carbon monoxide, nitrogen oxides and carbon dioxide, emitted per year is 12,140.30 lbs/year (or 0.97 lbs/mile) for vehicles. While our air engine is not emitting any gas other than compressed air.

6.2.2 Society

The bicycle remained an important part of the transportation sector in many areas of the world. The addition of air engine to the bike will be easy for the users so now they have to use less energy, especially for terrain areas where it is very difficult to ride it. Air engine bicycle can also be used for sporting purposes like in races air engine will give an extra boost to the bicycle.

6.2.3 Economy

Air engine bike is very economic for everyone as it isn't using any fossil fuel, which is very expensive as compared to compressed air. Air engine bikes are also cheap as compared to other vehicles. Due to air engine bike, society will move towards clean environment from which Government's doesn't need to spend a large amount of money to prevent global warming.

6.3 Contemporary Issues Addressed

There are some major challenges for GCC countries and Saudi Arabia in the coming time but one of the major challenges of GCC countries and Saudi Arabiais to diversify their societies from oil-based income to other sources of income, by decreasing the usage of products which needs fossil fuel to work.

Chapter 7: Conclusions and Future Recommendations

This chapter will wind up the entire project by summing up the main key points. The experiences and the practical knowledge gained, how the engineering theory was applied, and all the challenges faced will be discussed. Also, future recommendations will be provided in the latter section of this chapter.

7.1 Conclusions

This project has proved to be valuable and a memorable experience for all of the members. All of the key points and each members final review are detailed in the sections below.

7.1.1 Project Summary

Over the past few years, pneumatic systems have proved to be very effective and great at assisting the reduced reliance of fossil fuels. We have personally experienced this first hand working on our project. Although at a very primary stage, the engine works smoothly under the operation of pneumatic power. There is no fossil fuel being consumed and thus no harmful gases being exhausted. The implementation of the system on the bike is easy and can be done for any other type of bicycle. However, a few modifications would be required in order to accomplish that. Overall, the pneumatic powered engine has been very effective in accomplishing the objective that was set forth in the beginning.

The design of this project mainly involved selection of the right components for the system. Going through the possible options, we opted for an engine to work as the core component. Vane motors and pneumatic actuators were also very good options but they did not prove to be feasible for this project. The selection of the right engine was done through our calculations. These involved basic parameters, such as force, pressure, torque, power, etc, that were needed to find out the minimum requirements of the system. After acquiring the components, certain modifications were required in order for the system to work under pneumatic power. The engine was the one important component that required the correct modifications. The camshaft of the engine was converted into two stroke from a four stroke. This was necessary as the pneumatic system needed the cycle of two stroke operation to work. The other modification done to the engine was at the inlet and exhaust ports. These were reversed as the springs that were controlling the valves were different, where the inlet valve spring was stiffer than the exhaust valve spring. Changing them improved the exhaust stroke of the engine. The other modifications were done to the bicycle in order to fit the components.

The testing of the pneumatic powered system yielded important results. It was found out that when operating at the pressure of 10 bar, the cylinder would last for a total of 30 seconds. Changing the operating pressure varied the total time in a linear manner. Furthermore, the thrust provided by the engine was sufficient to ease of the riders efforts when cycling.

7.1.2 Project uniqueness

After the research in pneumatic systems, it was found out that the bicycles which were powered using pneumatic systems, mainly involved mechanisms such actuators. Our project however, uses an engine and this is capable of producing more power. Furthermore, we initially planned on designing a refueling mechanism for the pressurized air. We have theoretically come up with an idea that an engine can also work as a compressor to refuel the pressurized air when it is not being used to provide a thrust. So, our project is unique in a sense that the main component, which is the engine, can function as a mechanism capable of doing two separate tasks. It can both provide a thrust as well as refuel the pressurized air.

7.1.3 Members insight

Abdulelah Almarqabi

Working on the senior design project was a unique experience. It was the first time that I had to use most of what I have learned in regards of dynamics, design mechanics, and energy. I still felt like what I have learnt was not enough. One of the biggest challenges in senior design in general is understanding what course is best suited to deal with the problem and then actually applying the correct formulas and laws to that problem. I believe if it hadn't been for group discussions and looking over different task with different perspectives, I would not have felt confident in my four years of college education. A different perspective in looking at that challenge is that for the first time the project does not fall under one course, so there is no problem statement to look for hints on how to deal with the problem. We got to practice engineering by applying the scientific method, which includes the reliance on most natural sciences, to solve problem in the most efficient and economical way. I learned from this project that some problems might not look like or even be a topic or problem that I took in college, but I should not worry because I can rely on the research techniques. Also, I should feel confident in my education as it allows me to look at scholarly articles and science books and be able to understand the terminology and follow the thought process.

Sohaib Imran

My experience regarding this project was very satisfying. The work that needed to be done and the objective of the course was reasonable. I was able to utilize the knowledge that I had acquired over the past years and apply them practically into this project. The challenges that I faced initially were mainly about the integrity of the group as we faced some communicational problems during the start of the project. But once everyone was on the same boat, it was a smooth ride onwards. The challenges that I faced during the design phase were problematic. Yet, this was also solved by the groups teamwork and the assistance of our advisor. Through this project I have learned a lot about how a group works and what are the skills that are needed from an individual in order for them to contribute effectively.

Salman Siddique

The project experience was good, working with a team in this project helped me in acquiring many skills such as time management, critical thinking, problem solving etc. We have faced a lot of challenges during the project such as finding a compatible engine, selection of different materials as per the required standards. One of the biggest challenge faced was the piston movement with the help of air. First we had some problems, as the engine shaft was not rotating. But then as a team we solved this problem by performing some modifications on the camshaft. All in all, the overall experience was amazing and I have learned a lot of stuff which might help in my professional life.

Mohammad Faraaz

The project experience was very good, making an engine run on compressed air was a difficult task. But with the knowledge which my team and I have acquired over the year studying really helped us in making this dream project come true. The team was not coordinated at the beginning of the semester and all the member were having different ideas but ones we agreed on a single idea it was a smooth ride after that. The difficulties we faced was the piston movement and to fix this issue we came up with the idea to modify the cam and after that, the engine started working like a charm. The experience I gained from working on this project was amazing and I have also learned a lot about engines and other tool which are used in this project and this knowledge and experience which I have gained will help me in my professional career.

Abdullah Bashir

The experience in this project was great**.** The project objective of running the engine on a compressed air was unique and difficult. This project was done with the knowledge which I and my team members gained during the past four years in Prince Mohammad bin Fahd University. To run the engine on the compressed air we needed to modify the engine which was very difficult, as every member had his own ideas but we were able to combine the ideas and select the best one. The thing which I loved about this project was modifying the engine, I was able to work practically on this engine and was able to know the difference between a theory and practical work.

7.2 Future Recommendations

Due to a time restriction, the design and the selection of components was compromised in certain areas. For those interested in making a pneumatic powered system, it is highly advised that they manufacture their own two stroke engine. It will be more efficient and comparatively easier to implement it onto to the bicycle. It will be very helpful if the engine can fit in the middle section of the bicycles frame. This will improve the weight distribution of the bicycle and make it easier to sit on the bike.

We have mentioned refueling mechanisms in our literature review. We initially planned on making it a part of our project but the complexity of its design and mechanism forced us to withdraw this objective. We highly recommend that in the future our current project be used and a refueling mechanism designed for it. This can be a very good final year project.

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Appendix A: Progress Reports

	SDP – Monthly MEETING REPORT
	Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**Spring**	**ACADEMIC YEAR:**	**2018**
PROJECT TITLE	**Design of an air engine for a bicycle**		
SUPERVISORS	**Dr. Mohammad Asad, Dr. Nader Swalhi, Dr. Esam Jassim**		

Month: February

ID Number	Member Name
201400105	Abdulelah Almarqabi
201303504	Sohaib Imran
201303877	Salman Siddique
201400318	Mohammad Faraaz
201400533	Abdullah Bashir

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Project Summary + Chapter 1.2	Abdulelah & Sohaib	100%	Submitted
2	Gantt Chart	Abdullah & Salman	100%	Submitted
3	Chapter 1.1 and 1.4	Faraaz	100%	Submitted
4	Chapter 2	All Members	100%	Submitted

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	**Design of the air engine**	All members
2	**Fabrication of design**	All members
3	**Assembly of the design**	All members
4	**Midterm Presentation Preparation**	All members

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome f: An understanding of professional and ethical responsibility.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d1. Ability to develop team work plans and allocate	Fails to develop team work plans and allocate resources and	Shows limited and less than adequate ability to develop team work plans	Demonstrates satisfactory ability to develop team	Understands and applies proper and accurate team work plans and allocate

resources and tasks	tasks	and allocate resources and tasks	work plans and allocate resources and tasks	resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects
d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	Sohaib Imran	4	4	4	4
2	Salman Siddiqui	4	4	4	4
3	Mohammad Faraaz	2	3	2	4
4	Abdullah Bashir	3	3	2	4

Comments on individual members

Name	***Comments***
Sohaib Imran	Good work
Salman Siddiqui	Good work
Mohammad Faraaz	Good work
Abdullah Bashir	Good work

	SDP – Monthly MEETING REPORT
	Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**Spring**	**ACADEMIC YEAR:**	**2018**
PROJECT TITLE	**Design of an air engine for a bicycle**		
SUPERVISORS	**Dr. Mohammad Asad, Dr. Nader Sawalhi, Dr. Esam Jassim**		

Month: March

ID Number	Member Name
201400105	**Abdulelah Almarqabi**
201303504	**Sohaib Imran**
201303877	**Salman Siddique**
201400318	**Mohammad Faraaz**
201400533	**Abdullah Bashir**

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	**Design and calculations**	Abdulelah & Sohaib	100%	Submitted
2	**Material purchasing, manufacturing, and assembly**	All Members	75%	Submitted
3	**Presentation**	All Members	100%	Submitted
4	**Chapter 3**	All Members	100%	Submitted

List the tasks planned for the month of April and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	**Assembly of the system**	All members
2	**Testing of the system**	All members
3	**Completing the report**	All members
4	**Finalizing the project**	All members

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

<u>Outcome f:</u>

An understanding of professional and ethical responsibility.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

<u>Outcome d:</u>

An ability to function on multidisciplinary teams.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
d1. Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Understands and applies proper and accurate team work plans and allocate resources and tasks

d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects
d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	Sohaib Imran	4	4	4	4
2	Salman Siddiqui	4	4	4	4
3	Mohammad Faraaz	4	3	3	4
4	Abdullah Bashir	4	3	3	4

Comments on individual members

Name	***Comments***
Sohaib Imran	Very good
Salman Siddiqui	Very good
Mohammad Faraaz	Very good
Abdullah Bashir	Very good

	SDP – Monthly MEETING REPORT
	Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**Spring**	**ACADEMIC YEAR:**	**2018**
PROJECT TITLE	**Design of a pneumatic powered engine for a bicycle**		
SUPERVISORS	**Dr. Mohammad Asad, Dr. Nader Sawalhi**		

Month: April

ID Number	**Member Name**
201400105	**Abdulelah Almarqabi**
201303504	**Sohaib Imran**
201303877	**Salman Siddique**
201400318	**Mohammad Faraaz**
201400533	**Abdullah Bashir**

List the tasks conducted this month and the team member assigned to conduct these tasks

#	**Task description**	**Team member assigned**	**Progress 0%-100%**	**Delivery proof**
1	**Testing of the system**	All members	100%	Submitted
2	**Report completion**	All Members	75%	Submitted
3	**Final presentation and demo preparation**	All Members	100%	Submitted
4	**Report format**	Sohaib	100%	Submitted
5	**Design of brochure**	Salman	100%	Submitted

List the tasks planned for the month of May and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	**Final presentation delivery**	All members
2	**Demonstration of project**	All members
3	**Submission of full report**	All members

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome f: An understanding of professional and ethical responsibility.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d1. Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Understands and applies proper and accurate team work plans and allocate resources and tasks

d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects
d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

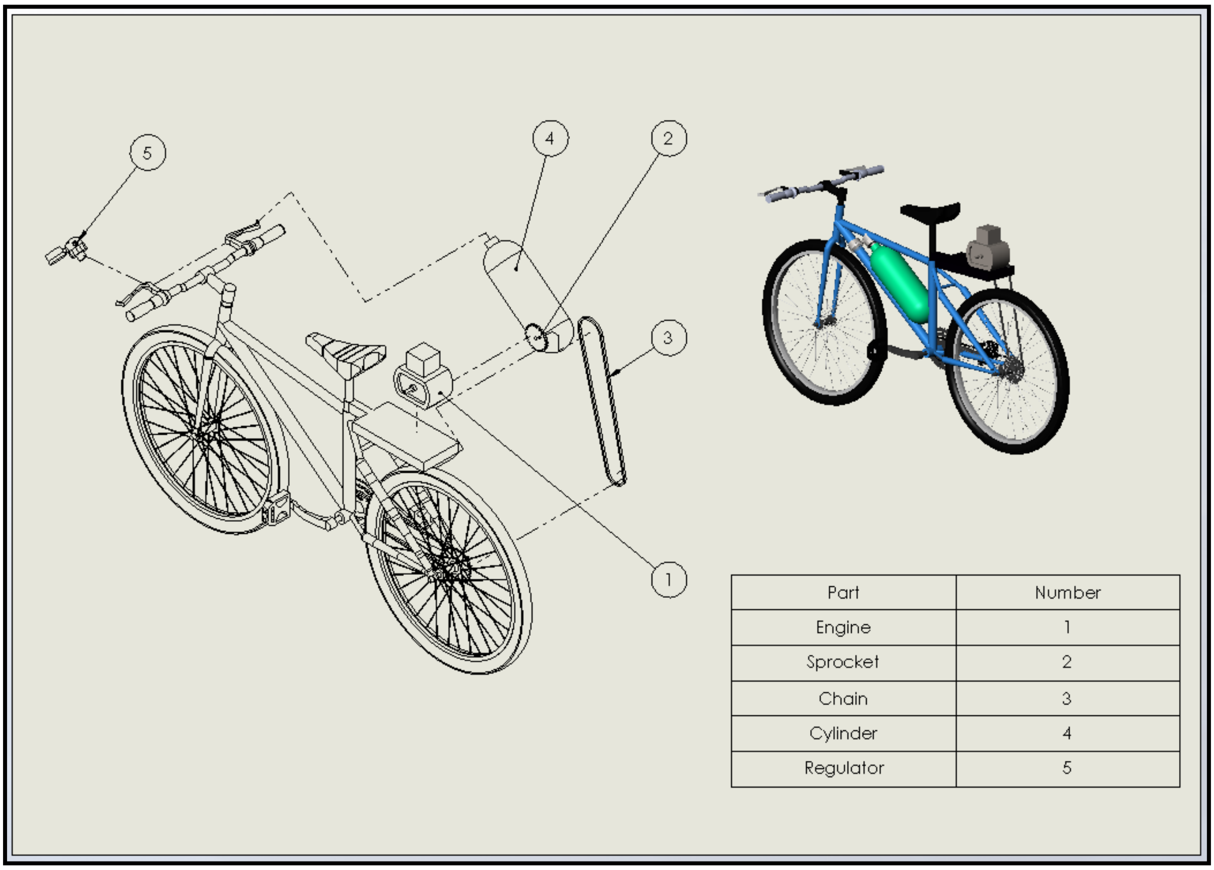
#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	Sohaib Imran	4	4	4	4
2	Salman Siddiqui	4	4	4	4
3	Mohammad Faraaz	4	4	4	4
4	Abdullah Bashir	4	4	4	4

Comments on individual members

Name	***Comments***
Sohaib Imran	excellent
Salman Siddiqui	excellent
Mohammad Faraaz	excellent
Abdullah Bashir	excellent

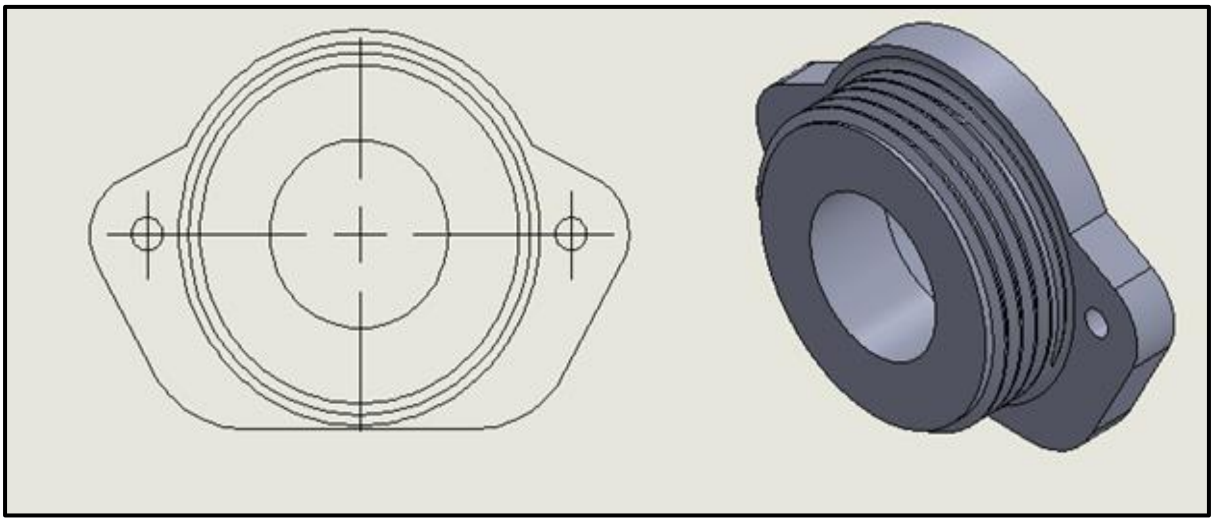
Appendix B: CAD Drawings

Bicycle Assembly

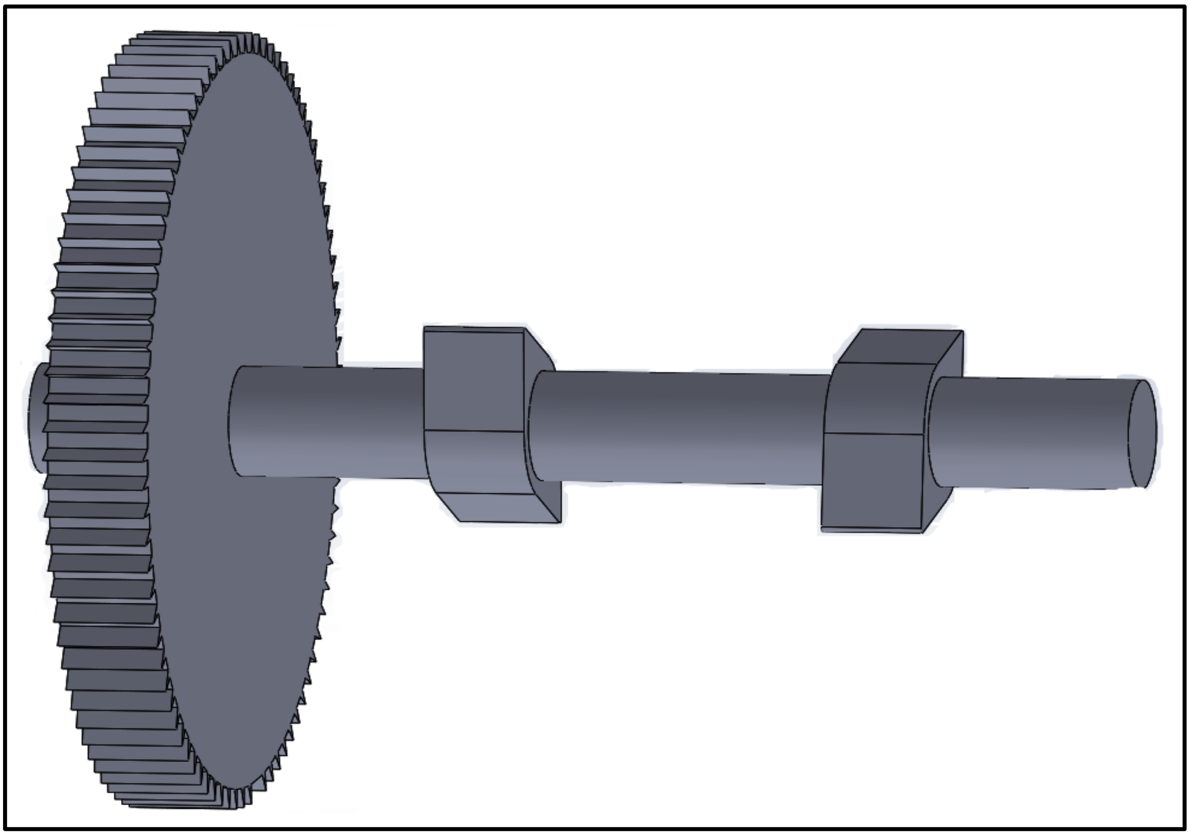


Part	Number
Engine	1
Sprocket	2
Chain	3
Cylinder	4
Regulator	5

Adapter



Camshaft



Appendix C: Tachometer Manual

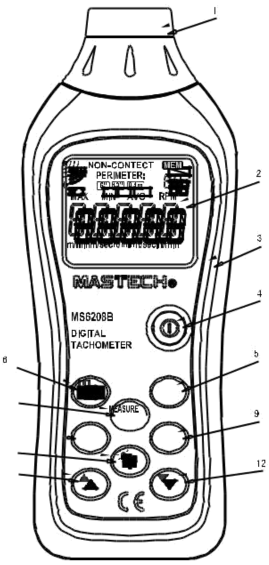
General Instructions

The MS6208B is a contact-type digital tachometer with stable performance, high reliability and high safety performance. The core component of the meter is a compact high-speed integrated chip. The meter calculates the exact rotation speed value through a reflected light sampling process. With a compact design, it is a meter with superior performance.

The meter will display rotation speeds from 50RPM---99999RPM. The LCD is backlit to allow making and reading measurements in low light conditions.

Panel Diagram (see front view)

1. Laser emission and receiving window
2. LCD display
3. Instrument case
4. Instrument power switch key
5. Maximum and minimum switch key
6. Hold key
7. Measurement key
8. Data storage key
9. Data storage read key
10. Backlight key
11. Storage read number plus key
12. Storage read number minus key



MS6208B Front View

Accessories

1. 1 MS6208B bare machine
2. 1 Operation Manual
3. 1 reflective sheeting
4. 4 x 1.5V AAA battery

OOBA (out of box audit)

When you get a new tachometer, check the meter and its accessories. If something is damaged or missing, please contact the store where you bought the meter to obtain missing items or to replace the meter.

Safety instructions

Operating environment:

- Elevation ＜2000 m
- Relative humidity (RH) ≦80%RH
- Operating temperature: 0 - 40°C Warning
- To avoid damaging the meter or affecting measurement accuracy, do not open the meter.
- Do not use the meter in the places with high

temperature and high humidity, or near flammable and explosive materials.

● Storage and maintenance: Do not use alcohol or

other solvents to clean the meter. If it is not used for long time, please remove batteries and put the meter in a dry and clean environment.

LCD description

1. Signal symbol
2. Low battery symbol
3. Maximum measurement display
4. Rotation speed reading display
5. Minimum measurement display
6. Storage state display
7. Storage number display
8. Average measurement value display
9. Measurement unit display

Key Description

1. Switch key

Function: On/Off operation

Operation: When the meter is OFF, lightly touch switch key to turn on the meter. When the meter is ON, lightly touch switch key to turn off the meter.

2. Maximum and minimum key

Function: Switch maximum, minimum and average display value

Operation: When the LCD display is MAX, current measurement is at maximum. When the LCD display is MIN, current measurement is at minimum. When

the LCD display is AVG, current measurement is average value.

3. Hold key

Function: Hold the current state of the meter Operation: When you press the key to hold, "H" will display on the upper right corner of LCD and the meter is HOLD state. Press HOLD key again to disable HOLD state, and the "H" on the upper right corner of LCD will disappear.

4. Measurement key

Function: Make laser tube illuminate for measurement

Operation: When turning on the meter, you can read the rotation speed of the object to be measured just by measuring according to operating instructions 5. Storage key

Function: Store current rotation speed value Operation: When you want to store the current rotation speed value, press the storage key together with other keys, and you can store the current value to the specified storage number.

6. Read key

Function: Read the rotation speed value under the stored number

Operation: When you want to store the rotation speed value under a storage number, press the read key together with other keys, and you can read the rotation speed value under the stored number.

7. Backlight key

Function: Turn backlight on and off

Operation: Turn the backlight on when pressing the key the first time. Press the backlight key again to turn the backlight off.

8. Plus key

Function: Add storage number when reading or storing

Operation: When entering storage state, press plus key to add the current storage number 9. Minus key

Function: Subtract storage number when reading or storing

Operation: When entering storage state, press plus key to subtract the current storage number

Technical Parameters

I. General specifications

1. Rotation speed display is five-digit LCD number with maximum of 99999

2. Display 0 below 50 RPM

3. Measuring distance is 50mm--250mm (when the battery voltage is sufficient)

4. Display voltage lower than 4.5V when batteries are low

5. Dimension: 155mm*60mm*27

6. Weight: 120g

7. Power supply: 4 × 1.5V SIZEAAA battery

8. Auto off time is 30 sec

II. Technical parameter

Measuring scope	Resolution	Accuracy
50-99.99RPM	0.01RPM	±(0.03%±2d)
100-9999.9RPM	0.1RPM	
10000-99999	1RPM	

Measuring operation instructions Warning:

To avoid injury, don’t aim at human eyes when measuring. Keep a safe distance from high-speed rotating objects to avoid machine damage or personal injury.

1. Paste reflective sheeting onto rotating disk or rotating shaft

To avoid inaccurate measurements, rotating disk or shaft can’t be highly reflective. If rotating disk is strong light-emitting object, cover it with black material before attaching reflective sheeting.

2. Fix the tachometer in a stable position and ensure that the light emitted from the tachometer is perpendicular to the object to be measured.

3. Start the tachometer. Start the object to be

measured. After rotation speed is stable, press the

measurement key and read the meter.

Note:

1. Because the meter measures and calculates the reflection time interval of light emitted from the meter, measurement is easily interfered with by extraneous light. Thus, measurement is not accurate if done outdoors in sunlight. Under such conditions, using the MS6208A contact-type tachometer is recommended.

2. If there is abnormal display due to vibrations or external light interference, release the key and press it again to reset the measurement reading to zero, and make measurements again.

Data storage and reading operation

I. Data storage operation

When you want to store rotation speed value, press

MEM key in the non-HOLD state. MEM and default storage number 00 will display on upper right corner of the LCD. Press plus or minus key to select storage number. At this time, if you pr. Press the backlight key, the rotation speed value will flash. The current rotation speed value can be stored in the selected storage number. Exit the storage state by pressing the READ key under the storage state.

II. Data reading operation

When you want to read stored values, press READ key in the non-HOLD state. The default storage number 00 will display on the upper right corner of LCD. Press plus or minus key to select storage number. At this time, if you press the backlight key, the rotation speed value will flash. Thus, you can read and display the value in the current storage number. It can exit the storage state by pressing the

MEM key in the storage state.

Battery installation or replacement

The power supply used by this meter is four 1.5V SIZE AAA batteries. To replace batteries, open battery cover, remove the old batteries, install new batteries of the correct size, according to the illustration on the cover. Close the battery cover after installation, and tighten screw before using the Meter.