PROJECT ANALYSIS

Final report

PROJECT GROUP 1

Mechanical Engineering

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Project Analysis: Engine Improvement

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Year of study: 2019/2020

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Preface (Intasar)

During this project our group learned about the functions of a small scooter engine and how we could improve those functions in order to improve the engine. The members were tasked to investigate and analyse several parts in depth. The group would like to thank Mr. Ruijter and Mr. Munuswamy for their enthusiasm and help during the project.

Summary (Intasar)

The report provides information about analyses and possible improvements of the two-stroke engine. The primary requirement that was taken into account in order to innovate the existing engine was increasing the power.
The report includes clear descriptions regarding how to achieve this and workouts of the operation of the engine parts, as well as material research and appropriate calculations that show the applicability and efficiency of the engine.

Function, manufacturing, materials choice, lab results and innovations of the parts of engine such as: Carburetor, Crank Shaft, Crankcase, Exhaust, Piston, Combustion Chamber, Reed Valve and Flywheel are presented in the report.

After complete analyses, the research provides feasible optimizations and information about new developments which may be applicable to this engine.

1. Introduction (Intasar)

This advisory report deals with the components that make up the 2-stroke engine, it offers sound research which ultimately helped us come to a conclusion as to whether any optimization can be done with the help of our newfound knowledge.
The engine was isolated into parts and those parts are divided into segments that tackle function, strength, manufacturing process and how they influence the effectiveness and efficiency of their workload. And if possible, whether any improvements could've been made in conclusion.

[1]2. Scooter (Tahsin)

Characteristics of a typical 50cc engine scooter are as follows:
Dry weight: 90 kgs (including the engine)
Braking: Front Hydraulic Disc; Rear Drum
Front Brake: 0.19 m diameter disc brake
Rear Brake: 0.19 m diameter disc brake
Wheelbase: 1.3 m
Length x Width x Height: 1.8 x 0.73 x 1.1 m
Saddle Height: 0.8 m
Front Tire: 130/70-10 or 120/70-13
Rear Tire: 130/70-10 or 140/60-13
Maximum Load: 100 kgs
Fuel Capacity: 4.2 to 8 L
Minimum Ground Clearance: 0.13 m
The above parameters can be considered as standard values and kept in mind when manufacturing a 50cc two stroke engine for a conventional commercial scooter.

1 is width, 2 is wheelbase, 3 is saddle height & 4 is length

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[1]

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3. https://www.aprilia.com/assets/aprilia-sites/master/models/Scooters/SR-50-R/tech-specs/2018/EN_Aprilia_SR50_R_technical_data/original/EN_Aprilia_SR50_R_technical_data.pdf
4. https://www.vespa.com/nl_NL/vespa-modellen/primavera/primavera-50.html
5. https://www.yamaha-motor.eu/gb/en/products/scooters/50cc/aerox-r/techspecs/
6. https://en.wikipedia.org/wiki/Scooter_(motorcycle)
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8. https://itstillruns.com/kind-foam-used-motorcycle-seat-6613742.html

3. The Engine (Paul & Ramon)

Our goal as a group is to develop our cheap Chinese motor into a far more capable motor through several improvements on the key components within it. To begin, we will focus our efforts on enriching the fuel mixture in order to allow for far better power to be achieved by the engine. This change will create a domino effect for the rest of the parts. We continue by adjusting our connecting rod to allow for more revolutions a cycle; we achieve this by shortening the rod and changing the material to titanium, which in return will lead us to changing the shape of the piston crown to a deflective one, apply ceramic coating on the piston crown and apply CT-3 Dry Lubricant coating on the piston skirt. We will also change the piston rings to a cast iron material as well as reduce the compression rings to 1. Finally for the piston we will be applying DLC to the piston pin. The crankshaft will then follow, we will change the material of the crankshaft bearings to aluminum, as well as improve upon the material of the crankshaft itself by opting for steel instead of iron. This choice that leads to a stronger part is also utilized for the flywheel where its aluminum is swapped for cast iron in order to adjust for the quickened pace of the motor. Now we will need to create a better balance within our motor, a reduction of the pressure within the crankcase and an increase of the compression ratio will do the job.

This kind of engine is used for different types of work. For example: motorbikes, scooters, lawnmower. The engine runs on a two stroke oil fuel mix. It has 4+ horsepower and it will rev up to 9000 RPM. You have to start the engine by pulling the start. It's fitted with a 15 mm carburettor. The transmission is an automatic direct drive which doesn't have a reverse gear. The 2-stroke oil is already mixed when it's coming to the carburettor. The engine is wind-cooled so the cylinder has to be in the open space.
Below you could find some data about the engine.
Volume flow: 0,4134 cm^3/s
Mass flow: 0,621 kg/s
Efficiency: 41,6%

Measurement	mm	inches
Bore Diameter	44	1.73
Distance Between Top Fixing Holes (centre of eye to centre of eye)	56.7	2.23
Distance Between Bottom Fixing Holes (Clutch Side, Centre of Eye to Centre of Eye)	55.2	2.17
Distance Between Bottom Fixing Holes (Pullstart Side, Centre of Eye to Centre of Eye)	65.9	2.59
Distance Between Bottom Fixing Holes (Pullstart to Clutch across, Centre of Eye to Centre of Eye)	83	3.27
Distance Between Bottom Fixing Holes (Pullstart to Clutch diagonally, Centre of Eye to Centre of Eye)	102.6	4.04
Length (Approx)	310	12.2
Height (Approx)	112	4.41

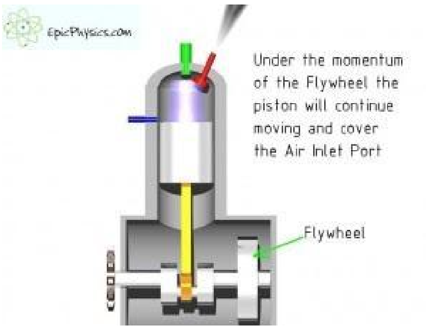
4.Analysis of the Components

4.1 Introduction (Intasar)

In this chapter a selection of parts from the engine will be analysed. The parts will be surveyed and their functions will be described and calculations will be performed when possible. Then the design of the part will be reviewed and possible improvements will be discussed.

4.2 Flywheel (Paul)

4.2.1 Function



The purpose of the flywheel is to store and supply kinetic energy to the engine to enable it to rotate during the periods when the engine is not producing energy, the flywheel does this by soaking up some of the energy from the power stroke as it starts to rotate faster. When the power stroke has done its part, its weight gives it the required inertia to continue to rotate. This is the energy that the piston uses to go back up and the crankshaft uses to open and close valves. One major concern for a flywheel is their weight, it must be just heavy enough to keep the engine turning over between power strokes. A two-stroke will typically have a lighter flywheel, as every other stroke is a power stroke, so less flywheel weight is needed.

4.2.2 Strength

The following results can tell us a lot about the conditions the flywheel faces within the engine. Looking at the results from the hardness tests we can see that the flywheel maintains something around a 980 hardness; meaning the material is most definitely strong enough to survive harsh conditions but at the same time it would be incapable of surviving such conditions for an extended period of time, mainly when considering its function. Taking a look at the material tests, we can see that the manufacturers opted to use an aluminium alloy as this is the purpose of implementing manganese into the material. The main reason for this pairing of materials is that both yield, and ultimate tensile strength increase significantly without decreasing ductility for the final result of the material.

Material Tests:

Element	Wt%	At%
MnL	33.76	20.02
AlK	66.24	79.98

HardnessTests:
Test 1: 972.04
Test 2: 983.78
Test 3: 983.78

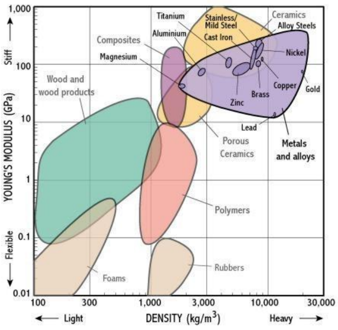
4.2.3 Manufacturing
A flywheel is used primarily in manual transmissions. It is attached to the engine crankshaft and holds the ring-gear that is used to crank the engine. The wheel connects directly to the clutch, stores energy to move the vehicle from inertia, and provides a friction surface for the clutch to attach to. Because of this, these parts are usually cast, and are thick and heavy, to allow for the clutch's surface.

In addition, the heavy weight allows for more inertia once it is spinning.
Flywheels are usually produced by the casting method, and for now, sand casting is the most common production process for flywheels. Depending on the application, the materials used are nodular iron, steel or aluminium. Once cast, the flywheel is finished by machining and boring.
Next, a square or rectangular steel bar of a present length is bent into a circle configuration and the ends welded together, with the major diameter larger than the finished gear size. The ring is then heated, and either stamped or bored to size on the minor diameter. Next, the gear teeth are hobbled onto the ring, and hardened to improve strength and resistance. Lastly, the ring is shrunk onto the flywheel.

4.2.4 Life Span
Generally, the flywheel suffers when the clutch wears out and results in slippage which overheats the FW and if enough the surface gets hard spots and will not resurface properly and will chatter and grab. Most clutches are designed to last approximately 60,000 miles before they need to be replaced. Some may need replacing at 30,000 and some others can keep going well over 100,000 miles, but this is fairly uncommon.

4.2.5 Possible Improvements
A possible improvement for a flywheel would namely constitute a change of material; as many researchers have shown that the optimal design for a flywheel is a 3-stroke design. For a change of material, what would be best is to make the material heavier by using brass or cast iron as they provide the greater weight, tensile strength, and are able to store high amounts of energy. This increase in weight will allow the engine to experience far smoother averages in torque and power as the added weight allows them to reduce the amount of jerking in the vehicle; this is achieved because of the flywheel's function of storing energy in order to make the next gas transition smoother. This is shown in figure 2 in which we can see that with à flywheel the torque line is far flatter, and if you were to add more weight this line would become even flatter as the flywheel will be able to keep its momentum going for an extended period of time. We could use à lighter flywheel but as research shows, their average is far less than that of à normal flywheel as they have many peaks and mins within their torque. This makes à lighter flywheel unreliable as sometimes you may have the power you need and other times you may not. The only true downsides of à heavier flywheel is that the startup of the engine will take longer as it needs to get à heavier flywheel turning and the price will be more as the material will cost more. But, this is okay since we are looking to give our engine as much power as possible, and the norm for a flywheel is for it to be made

of cast iron so we wouldn't be that far out of the norm. Although, cast iron is normally for [2] engines of a higher quality, the manufacturers of our engine must have realized that the way a flywheel will fail is if the clutch fails, so they just took the cheapest material they could get while still have a decent degree of tensile strength.



4.2.6 Conclusion

I believe that the part is well designed from a purpose point of view, as the overall quality could be far greater. But, as its purpose is to just barely provide the functional abilities of a flywheel, I would say this part does more than that as its hardness tests and material tests show that this part is unlikely to come under any stresses that would compromise the part. In all, the part does its job and is able to withstand the forces within an engine, but its overall quality could be greater in order to allow for the part to not just rely on the clutches lifespan but to also be able to survive on its own.

2

1. http://overdrive.in/news-cars-auto/features/simple-tech-flywheel-explained/
2. Nam, S. W., & Lee, D. H. (2000). The effect of Mn on the mechanical behavior of Al alloys. Metals and Materials, 6(1), 13–16. doi: 10.1007/bf03026339
3. http://ijaret.com/wp-content/themes/felicity/issues/vol2issue3/tony.pdf
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4.3 Crankshaft (Intasar)

4.3.1 Function

Figure 1: Crank Shaft

The crankshaft is a moving part of the internal combustion engine (ICE). Its main function is to transform the linear motion of the piston into rotational motion. It contains counterweights to smoothen the engine revolutions. Figure 1 shows the crankshaft.

The crankshaft in a two-stroke engine rotates, moving the piston by means of the connecting rod. These three parts are the only moving parts in a two-stroke engine. All power produced is a direct result of the action of these three moving parts.

4.3.2 Strength

There are two different load sources acting on the crankshaft. Inertia of rotating components (e.g. connecting rod) applies forces to the crankshaft and this force increases with the increase of engine speed. This force is directly related to the rotating speed and acceleration of rotating components. Variation of angular acceleration and angular velocity of the connecting rod for the engine speed of 3600 rpm is shown in Figure 1.

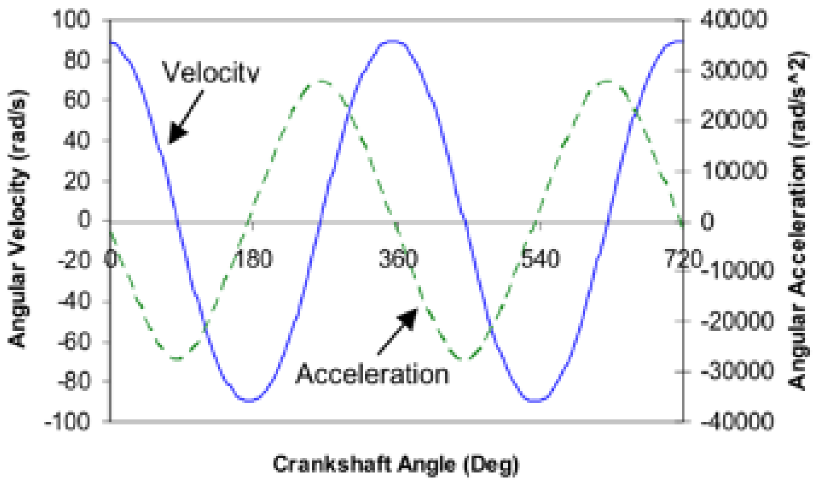

Figure 2: Variation of angular velocity and angular acceleration of the connecting rod over one complete engine cycle at a crankshaft speed of 2800 rpm.

The second load source is the force applied to the crankshaft due to gas combustion in the cylinder. The slider-crank mechanism transports the pressure applied to the upper part of the slider to the joint between crankshaft and connecting rod. Forces applied to the crankshaft cause bending and torsion. Figure 2 demonstrates the positive directions and local axis on the contact surface with the connecting rod.

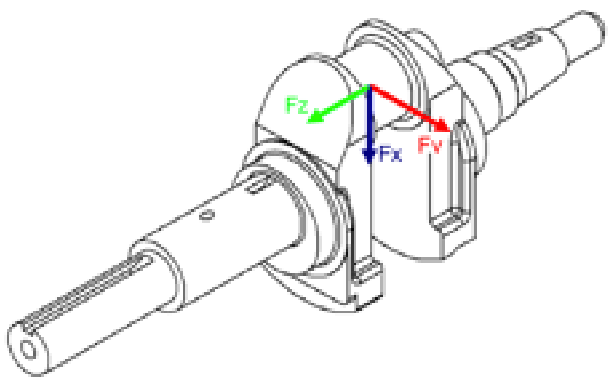

Figure 3:Crankshaft geometry and bending (Fx), torsional (Fy), and longitudinal (Fz) force directions

Figure 4 shows the variations of bending and torsion loads and the magnitude of the total force applied to the crankshaft as a function of crankshaft angle for the engine speed of 3600 rpm. The maximum load which happens at 355 degrees is where combustion takes place, at this moment the acting force on the crankshaft is just bending load since the direction of the force is exactly toward the center of the crank radius (i.e. Fy = 0 in Figure 3). This maximum load situation happens in all types of engines with a slight difference in the crank angle.

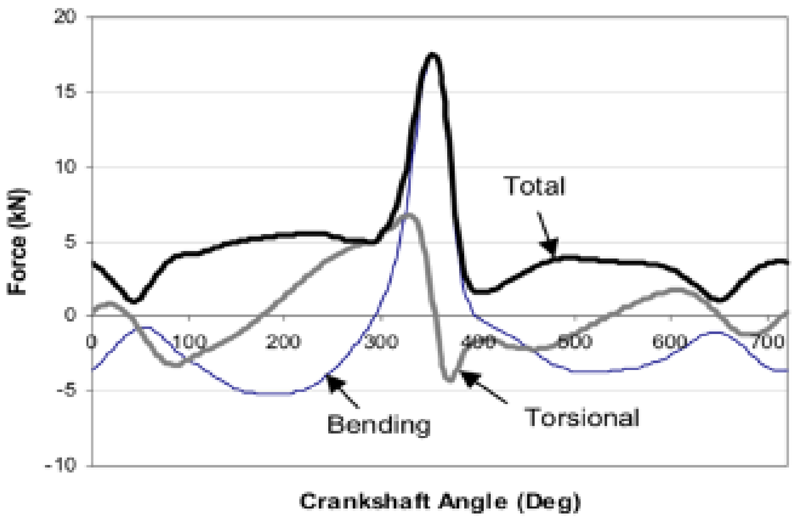

Figure 4: Bending, torsional, and the resultant force at the connecting rod bearing at the engine speed of 3600 rpm

4.3.3 Manufacturing

Composition of Crankshaft:

- 96.30% Iron
- 3.70% other

Crankshafts are one of the most crucial components of internal combustion engines and are subjected to very high dynamic loads during engine use.
Crankshafts are made from forged steel or cast iron.
Cast iron crankshafts are cheaper and less time consuming to manufacture than those made from forged steel. Metal may be more economically used in the casting process when the design of the crankshaft becomes more complex. The wear resistance of the main and crank pin bearings increases due to the presence of graphite in cast iron

4.3.4 Life span

Hardness of Crankshaft: 196.32

The hardness of the crankshaft is okay. It could be harder and better if a stronger material was used. It can withstand the stresses it is experiencing due to the hard iron material, but it will not last too long. Usually around 7000 miles.

4.3.5 Possible Improvements

One possible improvement is changing the material to steel rather than iron. Steel is iron mixed with carbon and perhaps other metals. It is harder and stronger than iron.

The crankshaft is essentially the backbone of the internal combustion engine. The crankshaft is responsible for the proper operation of the engine and converting a linear motion to a rotational motion.it also experiences quite a bit of stress. Crankshafts should have very high fatigue strength and wear resistance to ensure long service life. So replacing iron with steel can help make it stronger to withstand all the stresses and also prevent wearing to happen.

Another possible improvement is changing the material of the crankshaft bearing from iron to aluminum this will really improve the quality of the crankshaft by making it rotations smoother. This will allow less energy from being lost due to friction and allow more energy to go to the wheels. Also, the aluminum crankshaft bearing alloys are corrosion resistant and do not therefore rely on the overlay to protect them from corrosion.

4.3.6 Conclusion

In conclusion, Crankshaft serves as an important part of an engine in avoiding vibrational motion and it allows smooth transmission of power from the engine to various parts. Conversion of reciprocatory motion to rotational motion was made possible using crankshaft.

4.4 Crankcase (Intasar)

4.4.1 Function

The crankcase is the metallic case where the crankshaft sits and operates. Besides protecting the crankshaft and connecting rods from foreign objects, the crankcase serves other functions, it's an enclosed volume for the crankshaft motion and piston connecting rods to

move and operate.It also creates an enclosed area for pressurized lubrication of the metal-to-metal points of contact and movement. This enclosed area also provided 'slinging' of oil / lubricant to other moving parts and underside of pistons.

Another useful function is that it creates A sealed enclosure to keep dirt and moisture away from the moving parts. Some early reciprocating engines had open crankcases that were exposed to the elements. It was quickly determined that this shortens the life of the moving equipment.

4.4.2 Strength

Hardness of Crankcase: 89.07

It is very important for the crankcase to light weight because it is the biggest part of the engine. Aluminium is a light metal. The crank case is 88.792% Aluminum which is a fairly malleable metal, so it's not one of the strongest metals out there. The hardness value of the crank case was fairly low.

However, No Major forces are acting on the crack case making it extremely unlikely to fail due to the stresses acting on it.

4.4.3 Manufacturing

Composition of CrankCase:

- 88.792% Aluminium
- 11.208% Silicon

Crankcases and other basic engine structural components (e.g., cylinders, cylinder blocks, cylinder heads, and integrated combinations thereof) are typically made of cast iron or cast aluminum via sand casting. Based on the Material Analysis I did on a sample of the crankcase, I found out that the crank case was composed of

Process 1 – Radial Drilling Here in this first process, the dowel hole drilling is done. These are the holes which will help the crank case to be clamped in further machines.

Process 2 - Rough Milling &Final Milling.

[3]Process 3 - Vertical Machining Various processes are being done here which includes: Milling, Drilling, Boring, Tapping on top side of the CrankCase.

Advantage of Sand Casting:

- Lower cost production
- Quicker to cast
- Workers on all types of shapes

4.4.4 Life span

Crack cases usually last a while if they are well taken care of and checked regularly. An important reliability consideration is to make sure that the crankcase is securely mounted and is level. This requires proper grouting and maintaining a crack free (continuous) crankcase base support. Since the dynamic forces on the crank case can be very large, it is usual to use an epoxy grout, since they provide high bond strengths and are oil resistant. All reciprocating base plates should be continuously checked for any evidence of grout foundation cracks (discontinuities) and repaired at the first opportunity.

4.4.5 Possible Improvements

While many understand the merits of increasing the pressure of the air going into the cylinders, fewer understand the virtues of decreasing the pressure within the crankcase. Fortunately, the benefits of reduced crankcase pressure can also be accomplished by simpler and more cost-effective means.Optimized crankcase ventilation systems and the addition of a vacuum pump can swing positive crankcase pressures to zero (atmospheric). Once a solution is employed to reduce crankcase pressure, the result is ‘free horsepower’. This is ‘free’ in the sense that no additional fuel needs to be burned to release the power. Instead, the reduced crankcase pressure is simply freeing up new horsepower from increased engine efficiency and reduced power losses.

4.4.6 Conclusion

In conclusion, although the crack case is one of the biggest parts of the engine, and houses some of the most important parts, it really doesn’t need drastic changes done to it. It does its job pretty okay. However, for optimization sake, decreasing the pressure in the crankcase will help reduce crankcase pressure, this simply frees up new horsepower from increased engine efficiency and reduced power losses.

3
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4.5 Carburettors (Ramon)

4.5.1 Function

A carburetor is an engine device that is responsible for mixing air and fuel for internal combustion engines in the right/proper air-fuel ratio and supply the air-fuel mixture in form of fine spray. After the mixture is mixed, the mixture is sent to the cylinder for optimum burning. Nowadays the carburetors have largely been supplanted in the automotive industry by fuel injection. Fuel injection is another system that mixes air and fuel for internal combustion engines. The carburetors are still commonly used on small engines like; lawn mowers, scooters, generators and so on. The big advantage for using a carburetor is that you don't need any electrical systems to function. In this analysis we are analysing a carburetor of a small 50cc 2-stroke engine like in the figure 1.

Figure 1

Each engine has its own air-fuel ratio. This means that you can't switch a carburettor from one to another engine.
The carburettor works on the principle of Bernoulli's. Bernoulli's says that when the air is moving faster, the lower its static pressure is and the higher the dynamic pressure is. So it is not the throttle linkage that is responsible for the direct control of the flow of the liquid fuel.

In this next part of this analysis there will be a in depth explanation of the working of a carburettor.

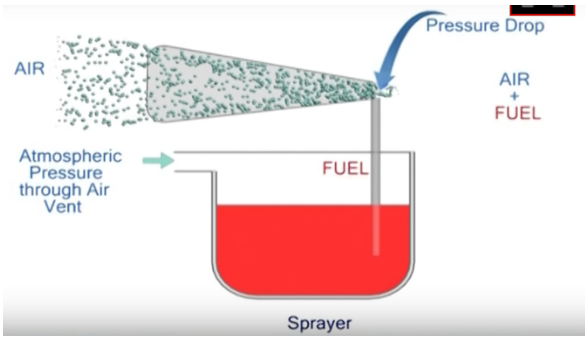


Figure 2

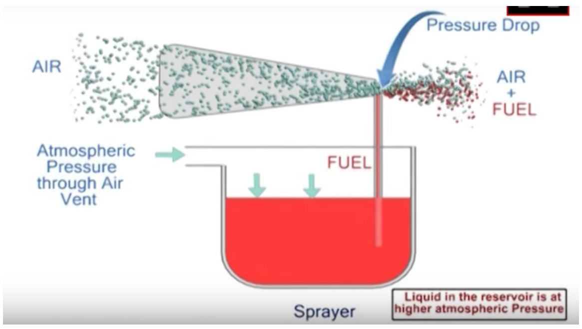


Figure 3

In figure 2 and 3 you can see a schematic representation of a carburetor. Air is going in the carburetor at a relatively low speed. Because the air intake has a big diameter in the beginning, the pressure in the beginning of the air intake is relatively high. The diameter of the air intake is decreasing, because of this the velocity of the air will increase and the pressure will reduce. At the end of the air intake there will be a drop in pressure. In the figures above, you can see a reservoir below the air intake. The reservoir is an open system, this means that there is an atmospheric pressure inside the reservoir. Because there is a pressure difference between the end of the air intake and the reservoir, the fuel (in red) will rise to the air intake and will mix with the air. This is the basic principle as to how a carburetor is working. The reduction in fluid pressure that results when a fluid flows through a constricted section of a pipe is called the Venturi effect.

Circuits in Carburettors

In almost every carburetor are 4 different circuits:

- Fuel inlet & float circuit: This circuit controls the fuel level in the float chamber
- Starter circuit: This circuit helps in starting the cold engine
- Pilot circuit: This circuit is used when an engine is running at idling, slow and medium speed
- Main circuit: This circuit is used when an engine is running at medium and at high speeds.

As the throttle opens, the speed of the engine increases. According to the speed at which an engine is running, the carburettors use the appropriate circuit for the delivery of fuel. In figure 4 you can see 4 different throttle positions. On the left one the engine will run stationary and on most right one the throttle is fully opened.

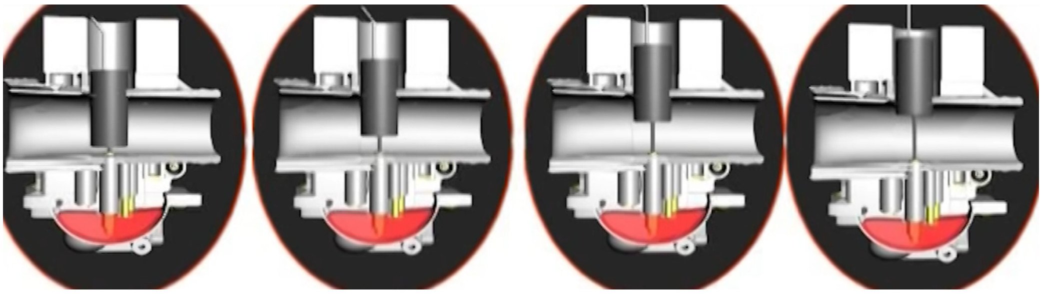


Figure 4

Different types of carburettors

For this type of engines there are two different sorts of carburettors. In figure 5 you will see these two types of carburettors.

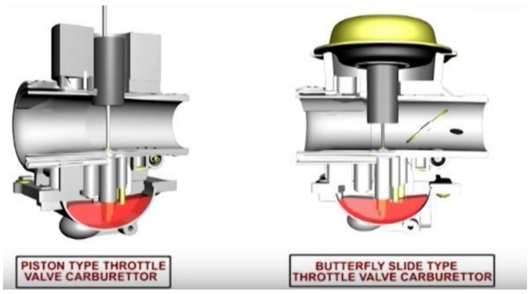


Figure 5

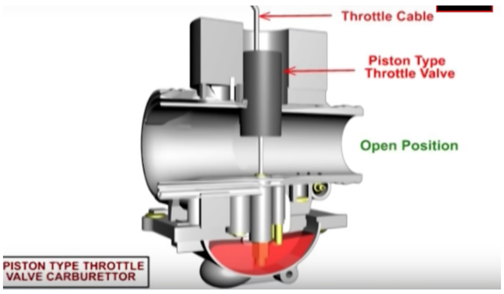


Figure 6

On the left side of the picture you see the ‘piston type throttle valve carburettor’. In this type of carburettor, venturi size is controlled by the piston valve, that is directly operated by the throttle cable (see figure 6).

In the engine that we will be analysing a ‘butterfly side type throttle valve carburettor’ is used (figure 7). In this type of carburettor both butterfly valve and the piston valve are incorporated. The butterfly slide throttle valve is located after the piston valve. The butterfly slide valve is controlled by the throttle cable. When the butterfly valve is opened, the velocity of gas in the passaged increases due the suction of the engine and the pressure will drop at the venturi area. When the pressure drops in the venturi area, the pressure in the above chamber of the diaphragm will also drop due to the hole in the piston valve (figure 8).

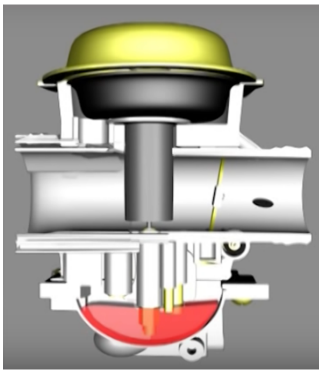


Figure 7

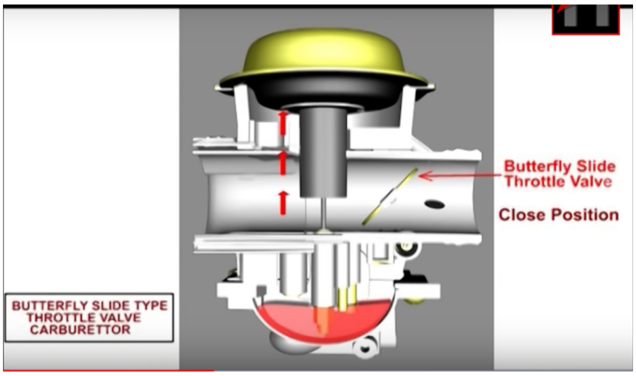


Figure 8

Connecting the upper chamber to the venturi the lower chamber of the diaphragm is at atmospheric pressure. Due to the pressure difference between the upper and lower chamber of the diaphragm along with the piston a jet gas needle is lifted up. This will cause the fuel to mix with the air in the required mixture. In figure 9-20 you can see the different parts that a butterfly carburettor consists of.

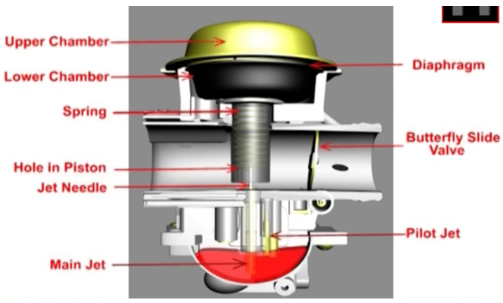
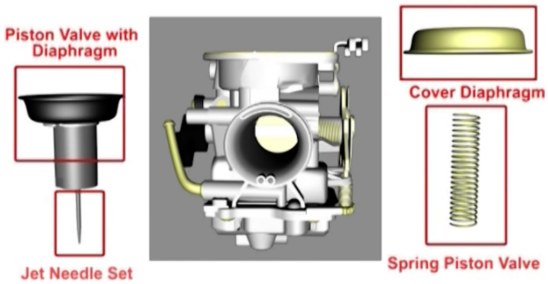


Figure 9



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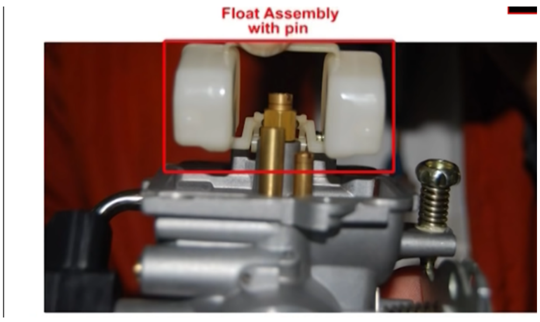

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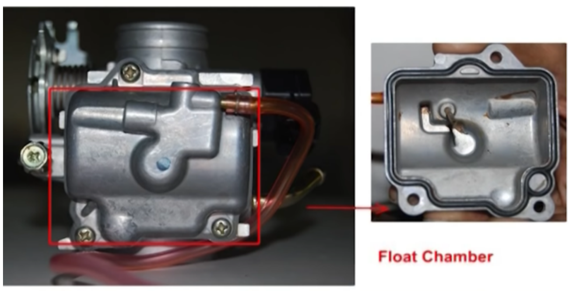

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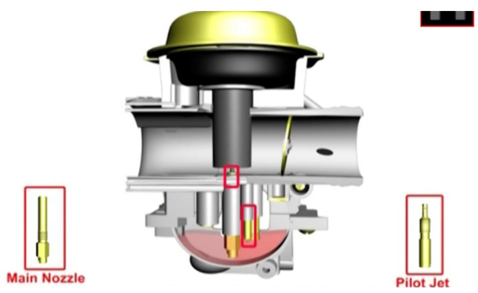

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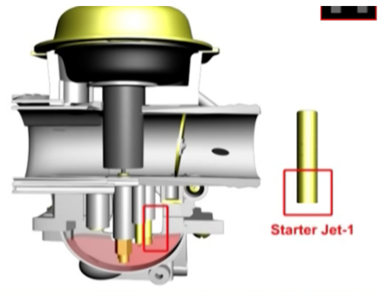


Figure 14

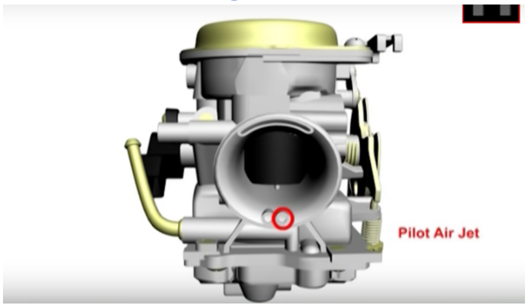


Figure 15

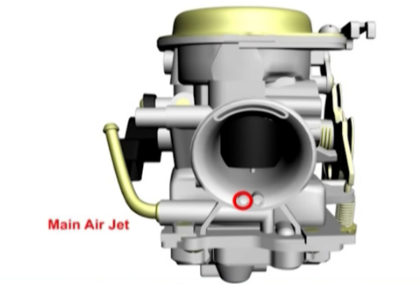
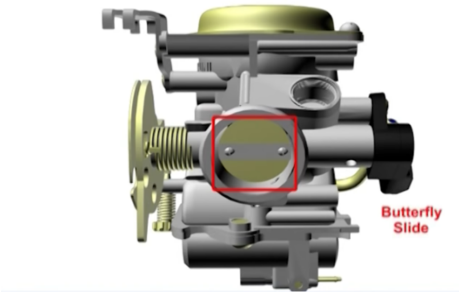


Figure 16



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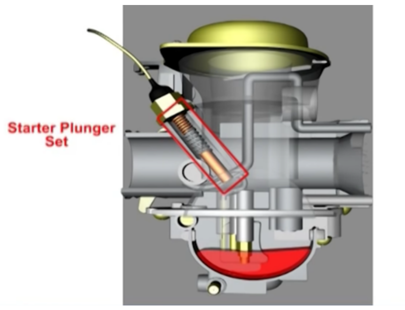

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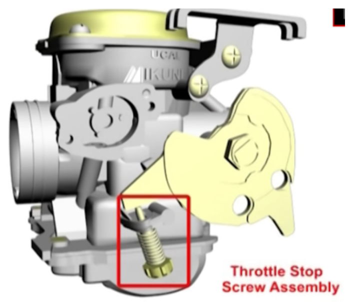

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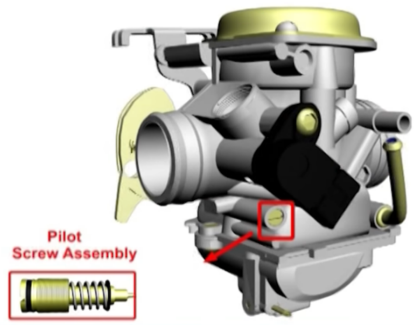


Figure 20

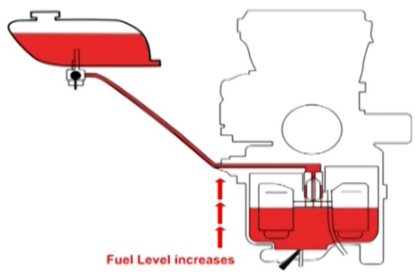


Figure 21

The fuel inlet system and float system of the carburettor consists of:

- Needle valve assembly
- Float
- Float chamber

The fuel from the tank enters the carburettor float chamber by passing through the fuel filter and the needle valve assembly. As the fuel level in the float chamber increases, the floater will start compressing the spring loaded pin of the needle valve. After the spring is fully compressed it closes the passage for fuel intake. In figure 21 you see a schematically representation of this part of the carburettor.

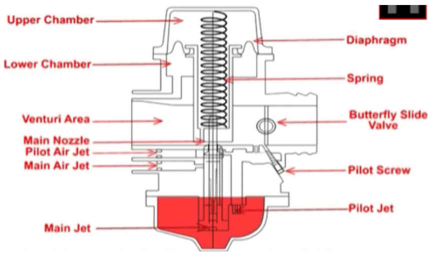


Figure 22

In figure 22 you can see all the different parts of a carburettor. In this figure all the different air jet channels are visible.

The butterfly valve is at an almost closed condition. By opening the butterfly slide, velocity of gasses increases in the venturi area. Because of the increase of velocity, a vacuum is created in the venturi area. The piston is lifted up due to pressure difference between the lower chamber and the upper chamber of the diaphragm. A controlled amount of fuel is sucked up to the mixing chamber through the main jet. If the butterfly valve is fully opened, the piston valve is also lifted fully along with the jet needle. Because of this the fuel is supplied mainly through the main jet.

To overcome the difficulty of starting a cold engine, richer mixture is provided through an additional circuit called a 'starter circuit'. This circuit is also called 'choke'. The starter circuit consist of the following parts:

- Starter cable
- Spring
- Plunger
- Starter Jet 1 (in some carburettors there is an additional starter jet)

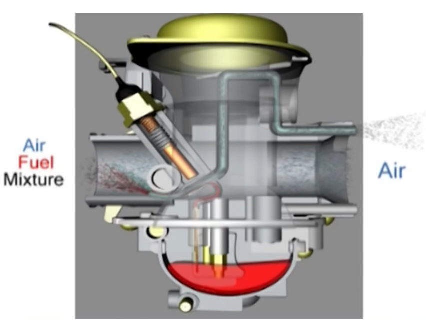


Figure 23

When the starter cable is pulled on, the starter plunger lifts up from its original position and the air enters the starting circuit through the starter air passage. This creates suction and fuel will be lifted up from the float chamber through the starter jets. Finally the mixture is drawn into the engine through the outlet provided in the main venturi near the carburettor outlet. In figure 23 you can see how this system is working.

In this next part of this analysis of the carburettor, we will analyse the different mechanism behind the three different circuits.

The pilot circuit provides the air-fuel mixture at idling, slow and medium speed. While idling the air enters the pilot circuit through the pilot air jet located in the pilot air passage see figure 15 . The pilot air circuit tube is decreasing in diameter so there will also be a Venturi effect. The fuel is fed to the mixing chamber through the pilot jet. From the mixing chamber the air-fuel mixture is sucked into the engine mainly through pilot outlet and is supplemented by the bypass. In figure 24 you can see how the pilot circuit is working.

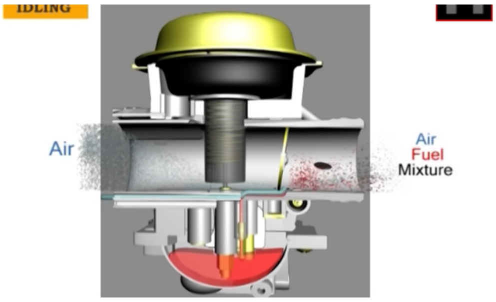


Figure 24

You can adjust the supply of the amount of air-fuel mixture with the pilot screw (figure 20).

The piston circuit provides the air-fuel mixture to the engine at slow speed. When the throttle valve opens the air-fuel mixture is fed into the engine mainly through the pilot outlet and the pilot bypass and is supplemented by the main circuit. In figure 25 you can see the working of the piston circuit.

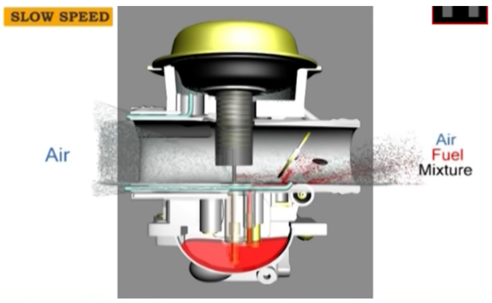
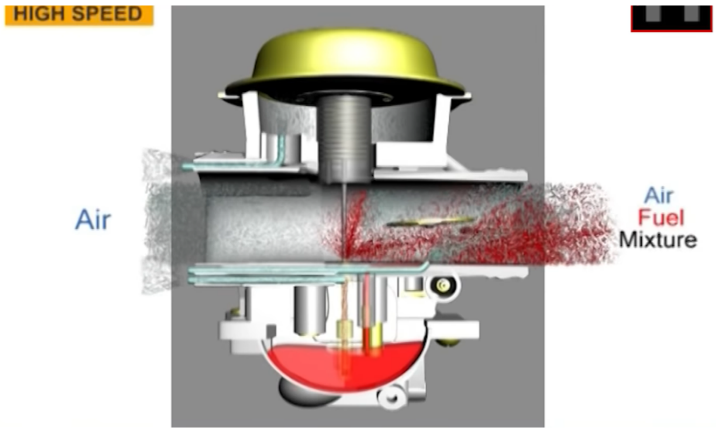


Figure 25

The main circuit provides the air-fuel mixture at medium to high speeds of the engine. The main circuit consists of the following parts:

- Butterfly slide valve
- Diaphragm
- Upper / lower chamber
- Spring
- Piston valve
- Hole in piston
- Jet needle
- Main jet

The functioning of the carburettor at medium to high speeds is similar to that of slow speed, except that the butterfly's side opens ¼ to fully open. This allows more fuel to enter from the main jet. Air enters the main circuit through an air passage and is controlled by the main air jet see figure 16. The controlled amount of fuel is sucked into the mixing chamber trough the main jet where it gets mixed with the air. Only the controlled amount of mixture is fed into the engine. The regulation of the mixture is done by the jet needle and the needle jet. The jet needle closes the needle jet when the piston valve is in closed position. In figure 26 you can see that the butterfly valve is located after the piston valve and is controlled by the throttle cable. When the butterfly's slide valve is opened, the velocity of gas in the passage increases due to the suction of the engine. Because of this the pressure drops at the venturi area. When the pressure drops in the venturi the pressure in the upper chamber of the diaphragm also drops due to the hole provided in the piston valve. This hole connects the upper chamber to the venturi. The lower chamber of the diaphragm is at atmospheric pressure, due to the pressure difference between the upper and lower chambers of the diaphragm the piston and the jet needle is lifted up. This generates a clearance between the jet needle and the needle jet, which results in a flow of required air-fuel mixture to the engine. In figure 26 you can see the working of the main circuit.



4.5.2 Strength
In our laboratorium session we analysed the materials of the different components of the carburettor.
We have analysed:

- The jet
- The throttle valve
- The outer case of the carburettor

First we have found the hardness of the material.

Jet	176,14 HV
Throttle valve	122,08 HV
Outer case	90,58 HV

After we found the hardness of the different components we analysed the material. We used an electronic microscope to determine the elements where the material is made from.

Jet	Cu (59,58%), and Zn (40,42%)
Throttle valve	Al (86,41%), and Si (13,59%)
Outer case	Al (81,82%), and Si (18,18%)

The values of the hardness test are very low, when you compare it with steel for example. But there is a reason why the material of the carburettor isn't that strong or hard. This is because there isn't a large pressure inside the carburettor. Also the carburettor is attached to the intake manifold, because of this the carburettor isn't encountered stress.

4.5.3 Manufacturing

Traditionally carburettors are made from a Zinc alloy. The main reason for this choice is it low cost, corrosion resistant and it melts at low temperature. Because of the complex geometry it is normally made by hot chamber die casting. Nowadays automobile manufacturers are trying to utilize the engineering plastics and composites for various parts of the carburettor. Because they will reduce the weight, fuel consumption will get lower. Furthermore, they will reduce the manufacturing and latter maintenance costs, since most of the engineering plastics are cheap and easy to recycle. Nowadays most carburettors are made from an aluminium alloy.

4.5.4 Life Span

Problems with the carburettors are often attributed to the part of becoming dirty. In addition, different parts can fail within the carburettor. For example, if the piston valve inside the carburettor is worn, a misfire in the engine will occur. Also flooding is a problem with carburetors that can be a dangerous situation. This will happen when dirt gets into the needle valve and prevents the valve from closing. Fuel-air mixture keeps flowing into the engine, but it won't ignite. Because of this the engine will get flooded and will not start. There is also a change that fuel will leak out of the carburettor and will fall on the hot engine. It is very important to clean the carburettor regularly.

4.5.5 Possible improvements

The main function of an carburettor is to mix the fuel with the air. Every engine has another fuel-air mixture ratio. This is why it is really important to fine tune the carburettor. You can adjust the next couple of thing to a carburettor:

- The jet gas needle

  The jet needle is adjustable. There is a clip and five little grooves that move the jet needle up or down. When you move the needle up, the fuel-air mixture will get richer (more fuel than air) and when you move the needle down, the fuel-air mixture will get leaner (less fuel than air).
- The main jet

  The main jet controls the air-fuel mixture when the engine is running at medium and at high speeds. The main jet is easy to change and you can adjust the diameter of the main jet. When a jet with a higher diameter will replace the original one, the fuel-air mixture will get richer. When a jet with a smaller diameter will replace the original one, the fuel-air mixture will get leaner.
- Pilot screw

  Most carburettors have a 'air idle adjuster screw' and a 'fuel idle adjuster screw'. With these 2 screws you can adjust the air-fuel mixture ratio in the pilot circuit. The pilot circuit provides the combustion chamber from the mixture when the engine runs idle. So when you want to change the RPM of idling, you can adjust these screws to effects the RPM.

[4]When you want to tune your engine or when you want to make your engine more efficient, you have to change your fuel-air mixture ratio. With the 3 parts above you can change your mixture. The aluminium alloy is already a light material, but when you want to make your carburettor even lighter you can make your carburettor from a lighter material. In the carburettor itself there are different circuits. The circuits of the carburettor have a friction coefficient. You can lower this friction coefficient to make the walls of the circuits smoother. The fuel-air mixture will undergo less friction.

4.5.6 Effects of possible improvements

When you are able to lower the weight of the carburettor, the lower the weight of the whole vehicle or motorbike. When you lower the weight of the vehicle the fuel consumption will also be lower. This is a small effect because the carburettor is already relatively light, so it won't be a very big difference. When you are changing the settings on the 3 parts above, it will be a big effect of the running of the engine. The gas mass flow entering and leaving of the carburettor will change when you change the jet and needle setup of the carburettor. Also the gas volume flow entering the combustion chamber will change. Because of the changes the power of the engine will get higher or lower and the fuel combustion will also change.

[4]

https://en.wikipedia.org/wiki/Carburetor
http://www.dansmc.com/carb3.htm
https://www.explainthatstuff.com/how-carburetors-work.html
https://www.youtube.com/watch?v=Gkhd-eJk234
https://www.carthrottle.com/post/carburettors-how-did-they-work/

Introduction (Julia)
I have chosen two parts to be researched: piston head and piston. None of our team members knew exactly what piston is and what piston head is from the whole piston structure, so I am going to describe my parts the way I think they should be.

Inside each cylinder is a piston that slides up and down creating the pressure inside the combustion chamber to make the powerful explosion, and as it does so, it turns a crankshaft that's attached to a gearbox, which in turn powers the car's wheels.

From (*figure 1)* you can see the piston. It has 10 main parts: oil-control ring (1), compression rings (2), wrist pin/ piston pin (3), circlip (4), piston skirt (5), bushing (6), bolts (7), liners (8), connecting rod shaft (9), connecting rod cap (10), piston crown (11).

Figure 1

4.6 Piston Crown (Julia)

4.6.1 Function

Function of the piston head is to transfer force from the combustion chamber to the crankshaft.

4.6.2 Strength

From the materials analysis were discovered that the hardness of the piston head is 141, 96 (*figure 1*).

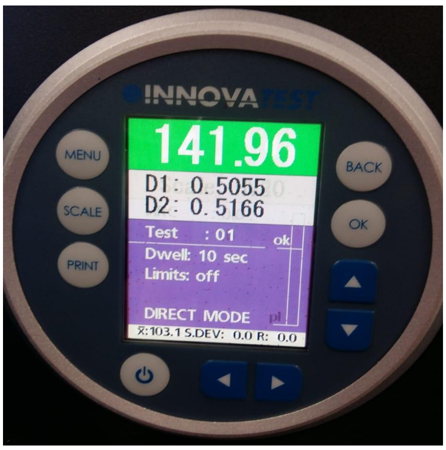


Figure 1

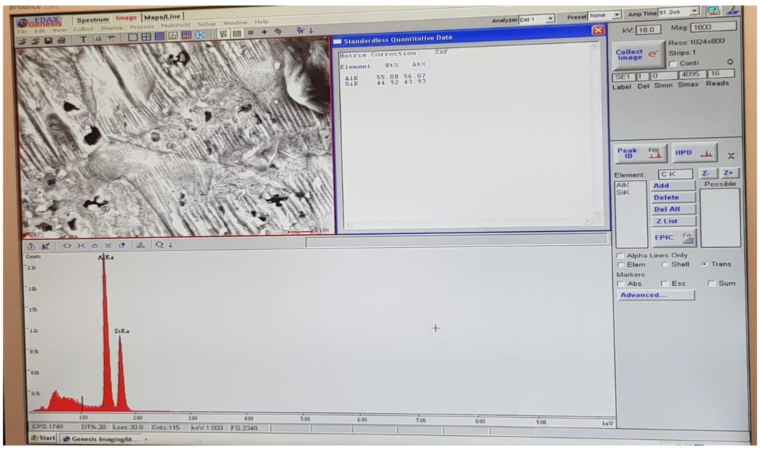


Figure 2

The material of the piston head contains two elements aluminum (55,08%) and silicon (44,92%) (*figure 2*).

After one of my team members calculated all needed values for the pV diagram I was able to calculate the force applied on the piston during the explosion in the combustion chamber.

Force=Pressure*Area

The highest pressure was in the moment of the explosion so at 3rd position in the pV diagram.

P = 8,990,468 Pa

By measuring the diameter of the piston crown, I was able to find the area of the piston head.

d = 4,1 cm
A=(d^2*π)/4
A=(4.1^2*π)/4=13.2025 (cm)^2=0.00132025 m^2
F=0.00132025 *8,990,468=11,869.704 N

4.6.3 Manufacturing
To manufacture a piston head there are quite a lot of different steps that are being done.
Step 1: 3-meter alloy of aluminum and silicon are being cut by the rotary saw.
Step 2: The punch press is heated up to 426 degrees Celsius, temperature required to forge the slugs, the slugs are also heated up to the same temperature in an oven.
Step 3: The punch applies 2000 tons of pressure to form the slugs into the initial shape of the piston.
Step 4: Cooling the forgings for at least an hour.
Step 5: Forgings are being heated twice more. Firstly, at a very high heat to strengthen the metal and, secondly, at a lower heat to stabilize it.
Step 6: Turning machine makes a correct shape for the forgings by reducing the diameter and cutting grooves for compression and oil rings.
Step 7: Milling machine makes a hole for the piston pin and shaves the piston from two sides to reduce the overall weight, another milling machine makes the crown of the piston.
Step 8: Worker removes sharp edges that may occur during previous steps.
Step 9: By using a belt sander the worker smooths out the surface.
Step 10: Cutting machine shaves off a bit of metal inside the pin hole in order to allow piston pin to fit inside.
Step 11: After all cuttings are being done the high-pressure jets spray the pistons with hot deionized water so that all traces of oil and lubricant are removed.
Step 12: An air gun blows dry the pistons. The pistons are ready.

4.6.4 Possible improvements

There are different shapes of piston heads. At the beginning piston head used to have only one shape, which was flat but later on researchers found that due to flat piston head the combustion of fuel does not take place properly which ultimately causes knocking in SI engines and improper emission in CI engines. From (*figure 3*) you may see the piston head with the flat crown.

Now we have piston heads with different crown shapes (*figure 4, figure 5, figure 6*). There are three reasons why this is so. Firstly, by not having flat pistons the engine has better fuel combustion. When the chemical reaction takes place at the time of combustion a flame front will produce which will affect the knocking factor. If this flame front does not generate properly then that will not count as a complete combustion. Due incomplete combustion sometimes unburnt fuel expels through exhaust pipe with exhaust gases. Secondly, when fuel comes inside the cylinder due to low pressure, it will have some kinetic energy, so the bucket type shape onto the piston will absorb most of fuel's kinetic energy and try to settle down the situation. Thirdly, the shape helps in reducing the overall weight of the piston because some amount of material has been reduced and reducing weight in automobiles is always advantageous.

Figure 3

As I mentioned before there are many different shapes of the piston crowns but still the best suitable crown for a two-stroke engine is a deflective one. Because our type of engine has a combustion chamber with the inlet and exhaust on the same level, there is a high chance that the coming mixture will pass across the combustion chamber straight into the exhaust. Deflective piston head has a raised rib on its crown. This shape deflects the incoming mixture upwards, around the combustion chamber.

To make a piston crown even better it is possible to apply a ceramic coating. This will decrease the heat coming to the piston by reflecting it to the combustion chamber, thus protect from deformations. In our case it would be wise to use Yttria-stabilized Zirconia because this is the king of ceramics is the best one for the Al-Si piston head.

Piston skirt may also have an improvement, such as providing piston skirt with a coating made of CT-3 Dry Film Lubricant, which provides low friction coefficient, intermittent dry lubrication, increase of a load carrying capacity, protection from the corrosion, chemical resistance, as well as that, if oil does not come sufficiently then this kind of a coating will prevent the piston from damage for some time.

Figure 4

Figure 5

Figure 6

4.6.5 Conclusion

In our engine's piston head, there are many ways to improve its efficiency. The only problem in such improvements is that they will drastically increase the expenses.

4.7 Piston Rings (Julia)

4.7.1 Function

The piston ring is an essential piston part (*figure 1*), and its numbers and functionality differ depending on the type and capacity of the engine. In 2-stroke large engines, compression type piston rings are used to seal the combustion chamber and wiper rings are installed below them to wipe the deposits from the liner and distribute oil on the liner surface.
Engine has three types of rings in it:

1. **Compression/ Pressure ring.** Main function of this ring is to seal the combustion gases and transfer the heat from the piston to piston walls. The compression ring is usually located in the first grooves of the piston.
2. **Wiper ring.** Premier function is to clean the liner surface off the excess oil and to act as support back up ring on stopping any gas leakage further down which escaped the top compression ring. Most of the wiper rings have a taper angle face which is positioned toward the bottom to provide a wiping action as the piston moves toward the crankshaft. Wiper ring is located right below the compression ring.
3. **Oil control ring.** The oil control rings control the amount of lubricating oil passing up or down the cylinder walls. These rings are also used to spread the oil evenly around the circumference of the liner. The oil is splashed onto the cylinder walls. These rings are also called scraper rings as they scrap the oil off the cylinder walls and send back to the crankcase. These rings do not allow oil to pass from the space between the face of the ring and the cylinder.

One of the most prominent materials used in making piston rings is cast iron. This is because it contains graphite in the lamellar form which itself acts as a lubricant assisting the sliding motion between the rings and the liner. The most common form of alloying cast iron is chromium, molybdenum, vanadium, titanium, nickel, and copper.
To be more clear in most four-stroke engines there are three different rings placed on the piston, since that four-stroke engines have a special oil system and oil rings help oil to circulate through the piston and to the combustion chamber and back. Moreover, two-stroke engines do not require an oil ring which means that this engine may work with only two or even one ring. In a two-stroke engine work of an engine partially depends on number of piston rings, so if a piston has only one compression ring then the engine will be working better at high rpm because then the friction is lower, and if an engine has two rings then life-span is longer and better sealing at a low rpm.

Figure 1

4.7.2 Strength

From the Material analysis became known hardness of the engine rings we are working on. The hardness is 286,54 (*figure 2*) and the weight of the part is 1,306 g. Material was not found since the piece of the ring was too small and could not be placed in the needed machine., the only thing which is known is that piston rings contain a huge amount (in percentage) of iron as it has magnetic properties.

Figure 2

4.7.3 Manufacturing

For the creation of a compression ring these steps are done:

Step 1: the manufacturing process for steel piston rings is simple; wire is cut from a spool of material measuring the desired proportions. There is no waste, and there are less steps from cutting to final product.

Step 2: as a piston ring face application, PVD has become more popular in the last several years. PVD is a thin coating that is deposited on the ring using titanium or chromium evaporated by heat with a reactive nitrogen gas. This process will make the ring very hard, smooth, and temperature resistant.

Step 3: lastly, gas nitriding is a heat process that impregnates the ring with nitrogen which will cause the ring case to harden. This process hardens the surface somewhere around .001-inch deep; the cylinder bore will show signs of wear before the ring when gas nitriding is used.

4.7.4 Lifespan

The modern design of compression rings was developed already in 1852 and in 1854 there was research into it and this design claimed a lifespan of up to 6437 km.

4.7.5 Possible Improvements

Our team has decided to improve engine in increasing the power, so one of the improvements would be the reducing quantity of compression rings to one. As I mentioned before, this will reduce the friction and allow the engine to work better at higher rpm.

Since from the materials analysis I was not able to find out the material from which piston rings are made of, it is impossible to come up with the possible improvements for particularly our engine, but I have made a research and found out what possible improvements there usually may be done.

One improvement is related to the change of material. Most commonly for the piston rings cast iron or ductile iron are used but the best material to use is steel, because steel piston rings are easy to manufacture, they are stronger and harder that ductile or cast iron one’s, furthermore, steel rings resist breakage, but the best advantage of steel is in that it can endure more heat stress from harsh environment and still hold its form without failure.

4.7.6 Conclusion

There is a possible improvement in piston rings, but it is not major and will not highly effect work of non-high-performance engines, however, reducing the number of rings may make the engine perform better. Still, if the changes will be applied when the cost of production will increase.

4.8 Piston Pin (Julia)

4.8.1 Function

Piston pin (*figure 1*) is made to connect the connecting rod and the piston head. Because of that piston pin must withstand extremely high loads in changing direction it is usually made of case-hardening or nitrated steel with a hardened, smooth ground and polished surface.

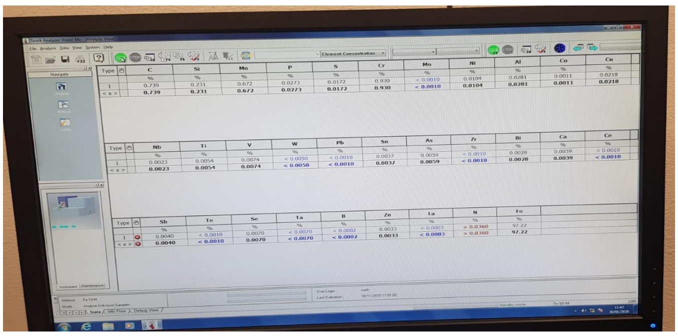
Figure 1

4.8.2 Strength

From the materials analysis were discovered that the hardness of the material of the piston pin is 633,12 (*figure 2*) with the weight of the piece 0,756 g.

Material of the researched piston pin part is mostly iron (97,22%), chromium (0,930 %) and carbon (0,739%) (*figure 3*).

Figure 3



4.8.3 Manufacturing

For the creation of a piston pin these steps are done:
Step 1: basic materials to produce piston pins steel wire or steel bars are used. They are cut and then formed in a sequence of operations.
Step 2: After that they are machined by turning, hardening and grinding.
Step 3: The finished components have a high surface quality and an accuracy of shape with a tolerance below 0.003 millimeters.

4.8.4 Possible Improvements

Since that the piston pin is the most stressed part of the engine its material must be very strong and smooth, the smoother material the higher rpm. The best improvement I could find is to apply the Diamond-Like-coating. This coating has a very high hardness 2000 - 2500 HV and a very low friction coefficient of 0.1, as well as that, its maximum permissible temperature is 450 degree Celsius.

4.8.5 Conclusion

As well as all improvements, improvement of the piston pin also implies increase of costs, but in my opinion this major part cannot be the one on which we should save expanses.

4.9 Connecting Rod (Julia)

4.9.1 Function

Purpose of the connecting rod (*figure 1*) also called a con rod is that it transfers the linear movement up and down of the piston head into the circular movement of the crankshaft thus transmits power. In other words connecting rod is a subject of tension, bending, compression and buckling.

Connection rods may be made of 4 different kind of materials:

- Micro alloyed steels;
- Sintered metals;
- High-grade aluminum;
- CFRP and titanium (usually for high-performance engines)

The main reason why manufacturers use these materials is that it is important to obtain minimal weight and high strength.

Figure 1

4.9.2 Calculations

From the material analysis I got to know that connecting rod is mainly produced from iron (95.95%) and some carbon (0.629%) and manganese (0. 620%) (*figure* 2) and the hardness of the connecting rod is 389.40 (*figure 3*).

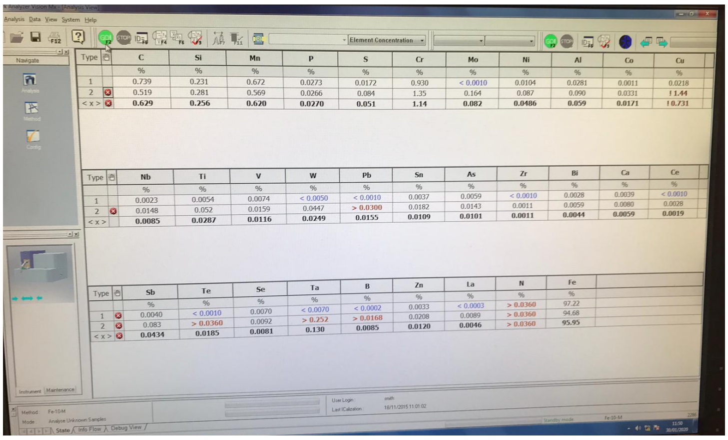


Figure 2

Figure 3

FP = FL ± FL ± WR

FL= 11,869.704 N

FI= Mass ×Acceleration= mR*wr*r(cosθ+cos2θ/4)

WR=mR*g

But since I do not have all the values, I was not able to find those forces

4.9.3 Manufacturing

There are a few steps to be taken to produce the connecting rod.
Step 1: Material selection.
Step 2: Cutting the material according to the required length.
Step 3: Billets heating.
Step 4: Hot forging.
Step 5: Piercing.
Step 6: Trimming.
Step 7: Shot blasting/ shot peeling.
Step 8: Machining (top surface, grinding the side faces, drilling the piston end, broaching of crank and piston rod, drilling of bolt hole, drilling of hole, machining of bolt head seat).
Step 9: Machine fracture splitting groove.
Step 10: Fracture splitting.
Step 11: Assembly of connecting rod.
Step 12: Machining (drilling crank and piston, milling of bearing of piston groove).
Step 13: Insertion of crank end bearing shells.
Step 14: Insertion of small end bearing bush.
Step 15: Inspection.

4.9.4 Possible Improvements

For connecting rod, it is possible to use different alloys of steel, aluminum and titanium. Every material has its own advantages and disadvantages. Firstly, steel alloys are long lasting but are heavy. Secondly, aluminum connecting rods are light, that allows to make heavier piston, and aluminum rod intakes vibrations, on the other hand, aluminum does not have a long life-span. Thirdly, titanium connecting rods are almost as strong as steel ones, besides they are also as light as aluminum ones. Connecting rod made of titanium has a disadvantage which is that the cost of this type of connecting rod is twice as big as steel connecting rods. Since one of the project tutors told us not to take into account the expenses, I would go for the titanium connecting rod.

As well as that, there is a possibility to increase or decrease the power and fuel combustion. If the connecting rod would be shorter then rpm will be higher at the same amount of time, but if the connecting rod will longer then the combustion will take more time and all the fuel will be burned. As I already said we are focusing on improving the power, so in this case the improvement will be shortening the connecting rod.

4.9.5 Conclusion

There are several possibilities of changes in the connecting rod which vary by the consumer’s desires.

5

[5]

1. https://www.google.com/search?tbs=simg:CAQSowIJoy4ZP0NYdqoalwILELCMpwgaYgpgCAMSKL4Gvwa9Bq8SihKZAqoGjBKwEqgSozOgNqQziz6fNvk28Tb4NqUzoTYaMGb4LQB4xTY4bK1BCN1ZhO-6BhM23B4Da4HpWvQKXJV0QaZIO2jKDv3xHBFYtJOLqSAEDAsQjq7-CBoKCggIARIEVeeSjAwLEJ3twQkajwEKIAoOZGlnaXRhbCBjYW1lcmHapYj2AwoKCC9tLzBkdzduChgKBWNodWNr2qWI9gMLCgkvbS8wNWtiOHcKGwoHZGllIHNldNqliPYDDAoKL20vMGg4anAzNgoWCgRsZW5z2qWI9gMKCggvbS8wNG40eAocCgh0aXRhbml1bdqliPYDDAoKL20vMDI1c2s1Ngw&sxsrf=ACYBGNR23RQoMBAJGloDKmLC1BjUQi1ybA:1580730164864&q=%D0%BA%D0%B0%D0%BC%D0%B5%D1%80%D0%B0+%D1%81%D0%B3%D0%BE%D1%80%D0%B0%D0%BD%D0%B8%D1%8F+%D0%B2+%D0%B4%D0%BD%D0%B8%D1%89%D0%B5+%D0%BF%D0%BE%D1%80%D1%88%D0%BD%D1%8F&tbm=isch&sa=X&ved=2ahUKEwi8n9nfprXnAhVOLewKHSmYDboQwg4oAHoECAcQKA&biw=1920&bih=969#imgrc=Ilu9kSgcjVA7hM
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5. https://avtoreview-msk.com/wp-content/uploads/2019/06/80895ed3a3ab714dfe98fd136695ad2f-333x250.jpg
6. https://static.turbosquid.com/Preview/2018/11/08__14_24_15/Piston_Connecting_Rod_33.pngEA1A333E-EBA9-4330-A50F-5B4E7C1F60FAZoom.jpg
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4.10 Exhaust (Tahsin)

4.10.1 Introduction

An engine exhaust system is a piping that lures reaction exhaust gases away from a controlled combustion inside an engine. Depending on the scale and working prowess of the system, there are one or several exhaust pipes through which the reaction gases are generally ejected into the atmosphere. The engine provided in the project is a two stroke one. Majority of an exhaust system is made from Stainless Steel and Aluminium.

4.10.2 Function

The main purpose of an engine exhaust system is to carry the exhaust gases away from the core engine which allows it to operate with minimal noise and maximum possible efficiency. A well-maintained exhaust system is an integral part of a long lasting and well performing automobile engine.

Each part of an exhaust system has its own unique function.

Exhaust Manifold: The exhaust manifold is the first component of the exhaust system. Its constituent is a Stainless Steel, Aluminium or Cast-Iron unit that adjoins the engine's combustion cylinders and collects exhaust gases from the combustion process. The exhaust is guided into a collector that directs the exhaust to the secondary components of the exhaust system.

Mufflers: A muffler contains a series of baffles that reduce the noise of the engine combustion and escaping gases. Without a muffler, the noise of combustion would escape directly from the exhaust pipe, creating a terrible ruckus and making the driving experience intolerable.

Catalytic Converter: The catalytic converter finishes the ignition of gases that have been incompletely burned within the engine's combustion chamber. The catalytic converter prevents hazardous gases such as carbon monoxide and nitrogen oxides from escaping into the atmosphere.

Tailpipe: The system ends at the tailpipe, which is made of Stainless Steel or Steel tubing. The exhaust pipe vents the reaction gases behind or above the vehicle.

In a two-stroke engine, as the one in the project, a bulge in the exhaust pipe known as an expansion chamber uses the pressure of the exhaust to create a pump that squeezes more air and fuel into the cylinder during the intake stroke.

4.10.3 Manufacturing

Production of an exhaust system has to be done in a systematic order. The steps can only be done one after another.

Gathering the appropriate and qualitative raw materials for production is the first step.

The preparation phase cuts the plates and pipes in the required dimensions.

Folding machine is the sector responsible for folding the pipes, through appropriate equipment and with adequate capacity. For this sector only pipes are to be folded, according to specifications of bend radius size and pipe diameter. Poly cut is the area where parts are cut in dimensions and size, according to specifications.

Stapling is the sector responsible for the closure of the central, intermediate and lateral silencer body. The process is carried out through the equipment able to join the ends of the plate, closing in a way that does not leak the gases or noise, thus isolating it so that it does not cause noise or respiratory pollution due to gases.

Circular Welding is responsible for welding the components (pipes), in a circular and uniform way with appropriate and automatic equipment.

Finally, proper inspection is needed for carrying out product approval or failure and releases the parts to the customer. Under the best possible conditions, an entire exhaust system can be constructed in around 68 minutes.

The muffler accounts for the lion’s share of the manufacturing costs of an engine exhaust system. The cost rotates around the desired quality and durability of the muffler as it is arguably the most important part of the exhaust system.

4.10.4 Life Span

The lifespan of an engine exhaust depends heavily on the frequency of the owner’s maintenance, the quality of combustion fuel being used, and the working load exerted on the engine. In essence, a lot of controllable factors determine how long an exhaust system will last. However, a rough estimation can be made assuming that the engine is looked after well, and the combustion fuel being used is of high quality.

A typical two stroke 50cc engine will last around 9500 kilometres under the above-mentioned circumstances. After that, it might either require an extensive refit, or it might give out completely.

4.10.5 Conclusion

The exhaust system marks the end of the working mechanism of an engine. Its significance to the whole cycle is no less than any other of the parts. It dictates the level of pollutants the engine will be releasing to the atmosphere, the audibility of the engine and also a great portion of the manufacturing cost behind it. Exhaust back pressure affects the power of the engine. Reduced back pressure leads to enhanced power supplied to the wheels, which in turn results in improved fuel economy. An exhaust system can either make or break the credibility of an engine.

4.11 Combustion Chamber (Tahsin)

A combustion chamber is a part of an internal combustion engine (ICE) where fuel is ignited. It is housed within the cylinder and is one of many several important components such as piston, sparkplug, and injector nozzle to be manifested there.


Figure 1


Figure 2


Figure 3

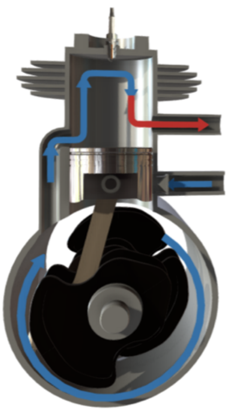
4.11.1 Function

The primary purpose of the Combustion Chamber is to allow the ignition of the fuel. It is the only place in the entire engine where this can happen. The piston compresses the fuel and contacts the spark plug, and then the mixture gets ignited. After that, the mixture is pushed out of the chamber in the form of energy.

The combustion process increases the internal energy of a gas, which translates into an increase in temperature, pressure, or volume depending on the configuration. This increase in pressure or volume can be used to do work, which in this case, is to move a scooter.

As seen in figures 1,2 and 3, the chamber contains 9 cooling fins on the side where the spark plug is connected, 6 on the opposite side where the exhaust outlet rests, and 11 on the two remaining sides. These are projections that increase the surface area from which heat can be radiated away from an object. The fins project outwards making the area for emitting heat back smaller than the area emitting heat to the outside environment. This means that the heat energy is efficiently transferred outside the object's housing. They have a very large surface area to let heat out to the surroundings as quickly as possible.

Overall, the air-fuel mixture enters the chamber and the piston moves upwards compressing this mixture. A spark plug ignites the compressed fuel and begins the power stroke. The heated gas exerts high pressure on the piston, the piston moves downward (expansion), waste heat is exhausted.



The engine in question is a gasoline engine. It is an ICE with a 'Heron Head' combustion chamber design. The chamber is located exactly on top of the piston. Advantages of such a design are simplicity of manufacture; compact dimensions; accuracy of

the flat machined surface; simplified valve-gear; efficient combustion with good fuel economy.
Disadvantages include: the greater size and weight of pistons; volumetric efficiency poorer than conventional cylinder heads.

When it comes to scavenging, the 50cc scooter engine follows cross flow scavenging. In this type, fuel is injected inside the combustion chamber through the inlet. Two spacings are located on the inner opposite sides of the chamber which allows for the smooth passing of fuel. After the combustion, the exhaust gases are pushed out of the chamber through the outlet. Figure 4 shows how cross flow in two strokes works.

Finally, the flame front is the instantaneous region from the spark plug up to which the flame has propagated, more specifically the instantaneous region up to which the fuel-air mixture is ignited. Ignition usually takes place at 288 Kelvin before the top dead centre (TDC).

TDC is the position of a piston in which it's farthest from the crankshaft. The spark plug must be sited so that the flame front can progress throughout the combustion chamber. Good design should avoid narrow crevices where stagnant "end gas" can become trapped, as this gas may detonate violently after the main charge, adding little useful work and potentially damaging the engine. Figure 5 manifests flame front inside the combustion chamber.

Figure 5

4.11.2 Strength

After performing two trials of Vickers hardness test on a 0.546-gram sample cut off from the combustion chamber, these are the obtained results:

Test 1			Test 2		
D1	D2	Hardness	D1	D2	Hardness
0.6170	0.6197	96.96	0.6207	0.6215	96.1

Average D1: 0.6189
Average D2: 0.6206
Average Hardness: 96.53

Material Composition of the sample: 100% Aluminium
Material density: 2700 kg/m^3

Diameter of the chamber: 4.5 cm
Height of the whole part: 9 cm *(approximately)*

Width of the whole part: 7 cm
Mass of the whole part: 343 grams *(approximately)*

Volume of the inner chamber: 0.00015 m^3 *(approximately)*

Mean effective pressure generated inside the chamber:

(Power x number of crank revolutions per power stroke) / (displaced volume per cycle x engine speed in revs per second)

= (5.575x10^3 W x 1) / (49x10^-6 m^3 x 200 RPS)

= **568877 Pa or 5.62 atm**

Maximum temperature generated inside the chamber:

(Room temperature) x (Compression Ratio) ^2 x (Ratio of specific heat - 1)

= (298 K) x (6) ^2 x (1.4 – 1)

= **1248 K**

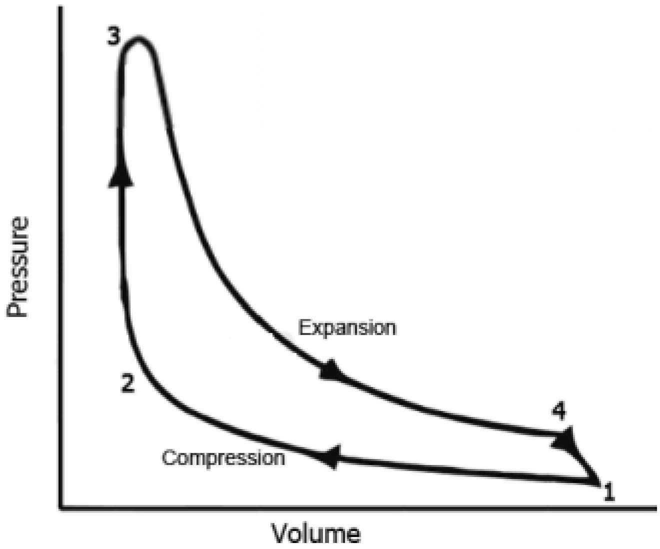
Mean effective force generated inside the chamber:

Mean effective pressure x Area of piston head

= (568877 Pa x 0.0013 m^2)

= **739.54 N**

Figure 6 below shows the thermodynamic cycle of a two-stroke gasoline engine:



Actual P-V Diagram for two-stroke petrol engine.

Figure 6

4.11.3 Manufacturing

Majority of the combustion chamber is made purely from Aluminium. The only exceptions being the inner part of the chamber which contains a coating of Chromium, and the spark plug.

A plating of Chromium is applied on the inner part because the hardness of Chromium is much higher than that of Aluminium. Thus, the strong intermolecular bonds of Chromium enhance the longevity of the combustion chamber and protects the inner Aluminium from deforming. Chromium can withstand heat and temperature much better than Aluminium due to possessing a higher hardness value. The maximum temperature generated during combustion is greater than the melting point of Aluminium, but less than that of Chromium. Without the added plating, the chamber would just melt because of the enormous temperature.

The combustion chamber is made through casting, and for now, sand casting is the most common production process. The material used is Aluminium. Then the holes for the spark plug, piston and outlet are bored. Finally, the chamber is finished by hardening it to enhance robustness.

4.11.4 Life Span

Combustion chambers are designed to last as long as the engine itself. The lifespan of an engine greatly depends on proper maintenance and severity of usage by the owner. A typical two stroke 50cc engine will last around 9500 kilometres under the above-mentioned circumstances. After that, it might either require an extensive refit, or it might give out completely. However, as stated before, the lifespan can be greater or less than the typical mileage due to deciding factors which rely on the user.

4.11.5 Possible Improvements

For the first improvement, a greater compression ratio can be considered as a feasible refinement. The compression ratio of the provided engine is 6:1. The basic point of a higher compression ratio is that the engine is getting more work out of the same amount of fuel. That's good for power, mileage and efficiency. Furthermore, higher ratio allows for an engine to extract more energy from the combustion process due to better thermal efficiency. Higher compression ratios allow the same combustion temperatures to be achieved with less fuel. That leads to a longer expansion cycle, more mechanical power output and lower exhaust temperatures. Finally, higher compression ratios produce more power, up to a point.

There are a few ways of increasing the compression ratio:

1. By reducing the cylinder diameter
2. By reducing the cylinder length/stroke length
3. By varying the air fuel ratio

Any of the above three mentioned steps may be taken.

As for the constituent material of the combustion chamber, it is far better to stick to Aluminium for this type of engine. An Aluminium head is more tolerant of high compression. Cast iron is more heat resistant, but it also weighs more than Aluminium. So, for a basic two stroke 50cc engine, there is no need of using any other material other than Aluminium as it already meets all the requirements quite well.

Increasing turbulence in the combustion chamber is another way of improving engine performance. This can be done by implementing the "squish" design in the combustion chamber. Squish is an effect in internal combustion engines which creates sudden turbulence of the fuel/air mixture as the piston approaches TDC. In an engine designed to use the squish effect, at TDC the piston crown comes very close, (typically less than 1mm), to the cylinder head. The gases are suddenly "squished" out within the combustion chamber, creating turbulence which promotes thorough fuel/air mixing, a factor beneficial to efficient combustion. Increased turbulence intensity results in decreased duration of the main combustion, but the burning rate increases rapidly as well. Figure 7 demonstrates the working principle and design of a chamber where "squish" is applied.

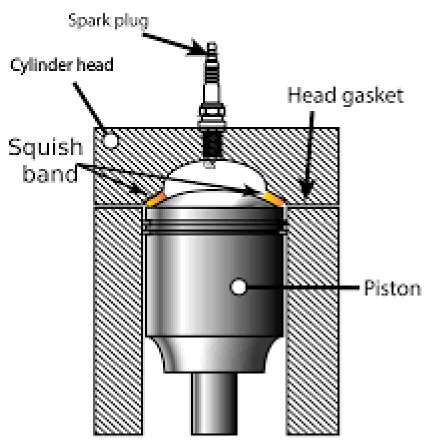


Figure 7

4.11.6 Effects of Possible Improvements

As compression ratio increases, the piston moves higher in the bore at top dead centre, hence there is additional force for the expansion stroke (additional force for the same amount of fuel equals higher efficiency). The higher the piston is in the bore when combustion begins, the more force will be exerted.

More mechanical work can be obtained from a high-compression ratio engine. There would be greater pressure in the cylinder and on the piston from the heat input from combustion. Thermodynamics dictates that thermal efficiency goes up with compression ratio. This equates to more horsepower and better fuel economy.

However, the more the air/fuel mixture is compressed, the more likely it is to spontaneously burst into flame due to high air-charge temperatures and pressures (before the spark plug ignites it). Gasolines higher in octane prevent this sort of early combustion. That is why high-performance vehicles generally need high-octane gasoline — their engines are using higher compression ratios to get more power.

As for the suggestion of increasing turbulence for achieving a faster burning rate, this is because the faster fuel burns, the more RPM can be gained. Greater RPM = greater power, if the amount of torque being produced can be maintained.

4.11.6 Conclusion

Combustion chamber is an individual part of the engine, but in several cases, its characteristics depend on the whole engine itself. That is, the chamber tends to work completely similar to the engine. From the thorough analysis, the following points can be concluded:

1. Aluminium is by far the best choice of production material for the combustion chamber of a basic two stroke 50cc engine.
2. Achieving a higher compression ratio for the engine is the preferred way for improving the chamber’s functionality. However, that comes with its own set of demerits.
3. The turbulence inside the chamber can be intensified by adopting a design for enhanced burning rate of the fuel, thus increasing RPM and power.

6

6

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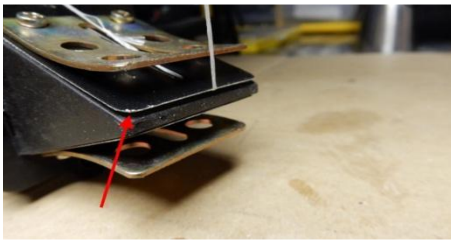
4.12 Reed Valve (Tomas)

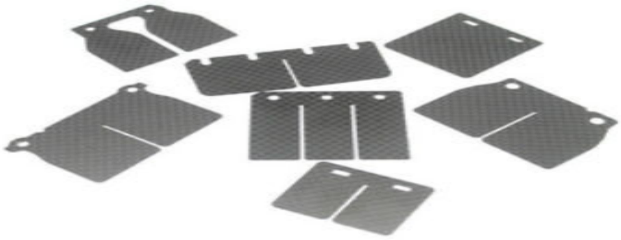
4.12.1 Description

The reed valve consists of thin flexible metal fiberglass or carbon fiber strips which are fixed on one end that open and close upon changing pressures across opposite sides of the valve. The reed valve frame is wedge-shaped the base is completely open and is the intake side area while on the side faces which are bigger there are windows which are the passage area on the crankcase side. An elastic thin reed called blades or petals and applied above such windows completely covering them.
In a former time, aluminum with a rubber coating was used to manufacture the reed valve. With this kind of technology there were no particular limits for the performance of the reed valve without diffuser but the cost of a typical production for motorsport was really high. At the same time, the delivery times and the lack of freedom of design and customization were absolutely unsuitable for the sports applications. What's more, the inserts diffusers were developed and manually manufactured, with many repeatability issues and without any scientific base they were made through plastering and further manual manufacturing handcrafted.

4.12.2 Function

The main function of the Reed valves is to regulate the flow of gases to a single direction. When the blades (petals) raise up allow the transit of the flow (homogenous mixture). This occurs while the outside pressure is bigger than the pressure inside of the crankcase. On the other hand, while the pressure inside the crankcase is bigger than the pressure outside then the valve closes. Moreover, the blade is the component that determines the system functionality and the valve opening and closing rule do depend upon its characteristics of the engine. Likewise, the reed valve function is to regulate the air & fuel mixture intake in the crankcase and the combustion chamber of a two- stroke engine. Another key fact to remember the fuel supply of a two-stroke engine gives especially the power and torque's output values.
Above all, without a valve, the gas would exit from the intake manifold and there wouldn't be enough pressure to allow the combustion chamber ignition. Similarly, this explains the importance of the continuous opening and closing of the reeds during each cycle in this way if a two-stroke engine reaches 14,000 rpm the reeds will do more or less 230 oscillations per second (Hertz) 1 RPM = 1/60 Hz.
When, we compared to the rotary valve's distribution and to the piston port. Firstly, the reed valve distribution allows versatility for the engine set up. Secondly, it also allows asymmetrical engine phases compared to the top dead point of the engine. Similarly, the reed valve distribution doesn't allow high rotation revolution and the expressed performances are slightly lower compared to a rotary valve distribution. Having said that, talking about the low and medium revolution the reed valve is more advantageous.





4.12.3 Requirements
The requirement of the reed valve is dependent on several aspects, for instance, the shape, thickness and the dimensions depend on the engine characteristics and is studied to reduce as much as possible the fluid dynamic loss. Likewise, the petals depend upon its characteristics and type of the engine.

4.13.4 Lifespan
Reed valves don’t have an exact expiration date, however depending on the material they are made of/and how it is used they can have a deadline. In many cases, reed valves that were made and used during the industrial revolution are still in use now. In general reed valve petals should be replaced in every 100 up to 150 hours. Having said that, we do have different kinds of petals like carbon fiber, Fiberglas, steel, aluminum therefore it varies the lifespan of the material. Likewise, when the petals couldn’t seal the opening you may need to replace the entire reed valve.

4.13.4 Material composition
During the analysis phase, I took upon myself to identify the different composition material we used for the reed valve of the current engine. I was able to achieve this through examination of the different parts of the current engine reed valve. During the examination I identified the composition, petals (C 0.123,Si 0.829, Mn 0.904, P 0.066, S 0.0180, Cr>9.96, Mo 0.106, Ni 6.53, Al 0.0071, Co 0.324, Cu 0.072)% and hardness value of 321.43 HV on the other hand the percentage composition of reed valve is Al 86.36 wt% &86.82 At%, Si 13.64wt% & 13.18At% and hardness value of 95.90HV.

4.13.5 Improvement
The most innovative aspects about improving reed valve is the material used and the results obtained are really huge, such as a better performance of the reed valve, a better repeatability and production speed and its lower cost, contrary, it can increase the cost. With this in mind, durability isn’t the only advantage of different kinds of reed materials. Significantly, a stronger, stiffer material allows the reed to be thinner and lighter. Notably, the lighter reciprocating mass of a reed increases performance.

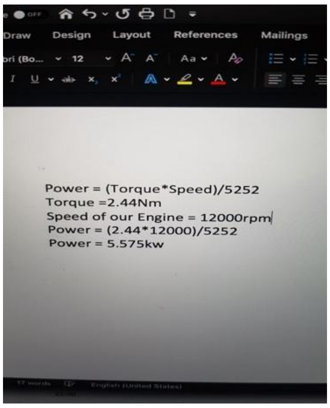
4.13.6 Conclusion
Therefore, the reed valve is a crucial component for the engine performance because, the reed valves act as like one-way check valves that prevent this backwash and regulate the flow of the fuel & air mixture to the engine. Moreover, the manufacturing material of the

reeds is very important because they have to face a big stress on top of that having a range of different stiffness' values. As a result, their thickness and consequently their stiffness determines high differences in the valve behavior. Lastly, the dimension, shape and type of material really affect the whole/entire system(engine).

[7]6. Calculations

A two stroke engine is far more capable than a four stroke engine in terms of its ability to deliver the power needed by the consumer. As for the manufacturer the process of creating the engine is far simpler and far more cost effective than à comparative model of a four stroke engine. To add to this its ability to be used in any orientation makes the go to for many oddly shaped machines. Ultimately, although the two stroke engine does have its downfalls, its niche abilities allow it to be used in certain situations in which a four stroke engine would have difficulties.

Calculating the power:



Power = (Torque*Speed)/5252
Torque =2.44Nm
Speed of our Engine = 12000rpm
Power = (2.44*12000)/5252
Power = 5.575kw

Calculating the Torque:
Using Footnote 7.1 we were able to determine the torque as being 2.44 Nw-m

P-v diagram data:

7

1. https://spicerparts.com/calculators/horsepower-torque-calculator

$$P3 := mgas \cdot Rs \cdot \frac{T3}{V3} = 8.99 \times 10^{6}\,Pa$$

$$P4 := P3 \cdot \left(\frac{V3}{V4}\right)^{1.3} = 8.753 \times 10^{5}\,Pa$$

$$T4 := \frac{T3}{\left(\frac{V4}{V3}\right)^{1.3-1}} = 2.577 \times 10^{3}\,K$$

$$Qout := mgas \cdot Cv \cdot (T4 - T1) = 113.87\,J$$

$$Qnet := Qin - Qout = 81.05\,J$$

$V1 := 58.8\,cm^3$

$P1 := 101325\,Pa$

$Cv := 718\,\frac{J}{kg \cdot K}$

$T1 := 298\,K$

$V2 := 9.8\,cm^3$

$$P2 := P1 \cdot \left(\frac{V1}{V2}\right)^{1.3} = 1.041 \times 10^{6}\,Pa$$

$V3 := V2 = 9.8 \times 10^{-3}\,L$

$$T2 := \frac{T1}{\left(\frac{V2}{V1}\right)^{1.3-1}} = 510.107\,K$$

$$T3 := T2 + \frac{Qin}{mgas \cdot Cv} = 4.411 \times 10^{3}\,K$$

$Qin := 194.92\,J$

$mgas := 6.96 \cdot 10^{-5}\,kg$

$Rs := 287\,\frac{J}{kg \cdot K}$

$V4 := V1$

process 3 - 4 Isentropic Expansion (4)

$V_4 = V_1 = 58.8\,cm^3$ ∴ The process is Isobaric

$\Delta u = 0$

$P_4 = P_3 \left(\frac{V_3}{V_4}\right)^{\gamma} = 8990468\,pa \left(\frac{9.8 \times 10^{-6}\,m^3}{5.88 \times 10^{-5}\,m^3}\right)^{1.3}$

875 kpa

$T_4 = \frac{T_3}{\left(\frac{V_4}{V_3}\right)^{\gamma-1}}$ or $T_4 = T_3 \left(\frac{V_3}{V_4}\right)^{\gamma-1} = 4407K \left(\frac{9.8}{58.8}\right)^{1.3-1}$

$= 2574K$

$Q_{out} = m\,c_v\,\Delta T$

$m_{Gas}\,C_v(T_4 - T_1)$

$6.966 \times 10^{-5}\,kg \times 718\,J/kgK\,(2574K - 298K)$

113.83 J

$W_{net} = Q_{IN} - Q_{out}$

194.92 J − 113.83 J

84.083 J

process 2-3 Isochoric process. (3)

Mass gasoline $= \frac{1\,mgas}{15.7} = \frac{6.966 \times 10^{-5}\,kg}{15.7} =$

$0.443 \times 10^{-5}\,kg$

Energy Density of Gasoline : 44 MJ/kg -

$Q_{in} = M_{Gasoline}[44 \times 10^{6}\,J/kg \times 0.443 \times 10^{-5}\,kg]$

194.92 J

$Q_{in} = m\,c_v(T_3 - T_2)$

$\frac{Q_{in}}{m\,c_v} + T_2 = T_3 = \frac{194.92J}{718\,J/kgK \times 6.966 \times 10^{-5}\,kg} + 510K$

4407 K

\# $V_3 = V_2 = 9.8\,cm^3$

$PV = mRT$

$P_3 = \frac{m R_s T_3}{V_3} = \frac{6.966 \times 10^{-5}\,kg \times 287\,\frac{J}{kgK} \times 4407K}{9.8\,cm^3}$

8990468 pa

$V_2 = \frac{\pi}{4}\,40 \times 10^{-1} \times 70mm$ (I just consider $L_2 = 7mm$ b/c I could now L_2?)

I'm not sure = $8.79\,cm^3$? (But I got this value aproximatly from Internet)

But I found something wh is more ~~Convenient~~. Convenient.

\# $V_2 = \frac{V_1}{\text{Compression ratio}} = \frac{58.8\,cm^3}{6/1} = 9.8 \times 10^{-6}\,m^3$ or $9.8\,cm^3$

$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{\gamma}$ — It is hard to find γ I got this one 1.3

$= 101325\,Pa \left(\frac{58.8\,cm^3}{9.8\,cm^3}\right)^{1.3}$

1040 Kpa

\# $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1} = 298K \left(\frac{58.8\,cm^3}{9.8\,cm^3}\right)^{1.3-1}$

510 K

$V = 49\,cm^3$

$L = 39\,mm$

CR = 6 : 1

Piston Displacement :- Area Bore × Stroke × # Cylinders

$\frac{\pi}{4}(40 \times 10^{-1})^2 \times 39 \times 10^{-1}\,cm$

$49\,cm^3$

$4.9 \times 10^{-5}\,m^3$

$V_1 = \frac{\text{Displacement Volume}}{1 - \frac{1}{\text{compression ratio}}} = \frac{49\,cm^3}{1 - \frac{1}{6/1}} = 58.8\,cm^3$

process 1 - 2 Isentropic Compression

P_1 = atm = 101,325 pa

$T_1 = 298°K$ Room temprature

$R = 287\,J/kgK$

$PV = mRT$

$m = \frac{PV}{RT} = 101.325\,kpa \times \frac{V}{RT}$

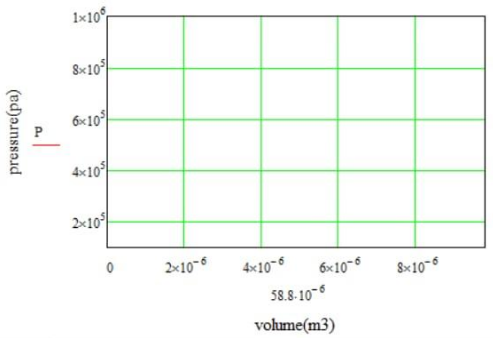
$6.96 \times 10^{-5}\,kg$

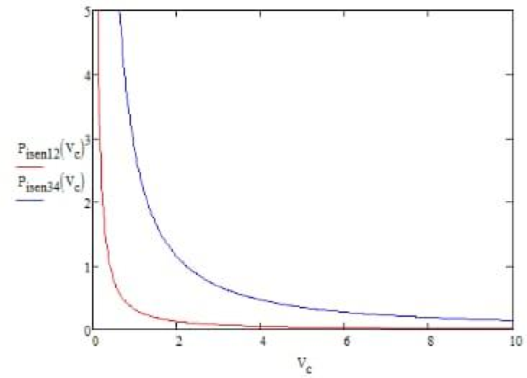
$$Cisen12 := (P1 \cdot V1)^{1.3} = 10.177 \frac{m^{2.6} \cdot kg^{1.3}}{s^{2.6}}$$

$$P_{12}(V_c) := \frac{Cisen12}{V_c^{\ 1.3}}$$

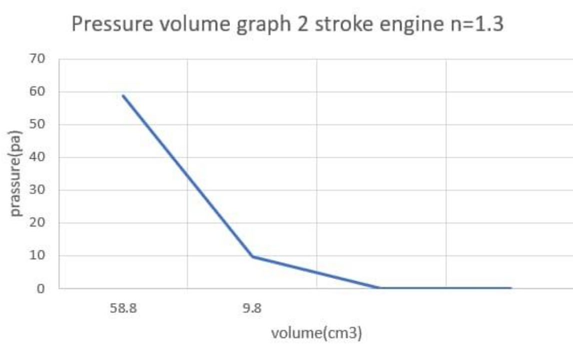
$$Cisen34 := P3 \cdot V3^{1.3} = 2.769 \frac{m^{2.9} \cdot kg}{s^2}$$

$$P_{34}(V_c) := \frac{Cisen34}{V_c^{\ 1.3}}$$

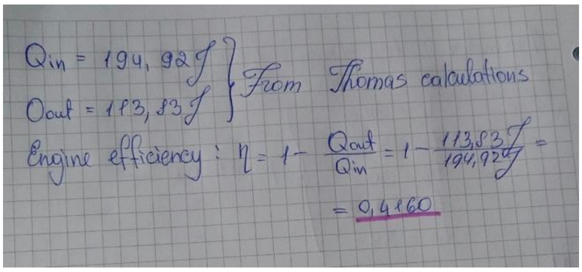




Volume(cm3)	pressure(pa)
58.8	101325
9.8	1040 670
	8990468
	875358

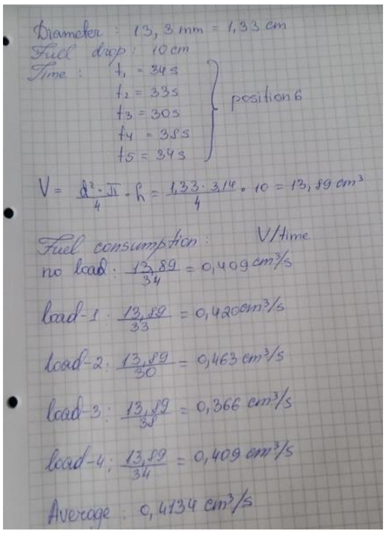


Engine's net efficiency:



$Q_{in} = 194,92\,J$
$Q_{out} = 113,83\,J$ } From Thomas calculations

Engine efficiency: $\eta = 1 - \frac{Q_{out}}{Q_{in}} = 1 - \frac{113,83\,J}{194,92\,J} =$
$= 0,4160$



Diameter: 13,3 mm = 1,33 cm
Fuel drop: 10 cm
Time: $t_1 = 34\,s$
$t_2 = 33\,s$
$t_3 = 30\,s$
$t_4 = 38\,s$
$t_5 = 34\,s$ } position 6

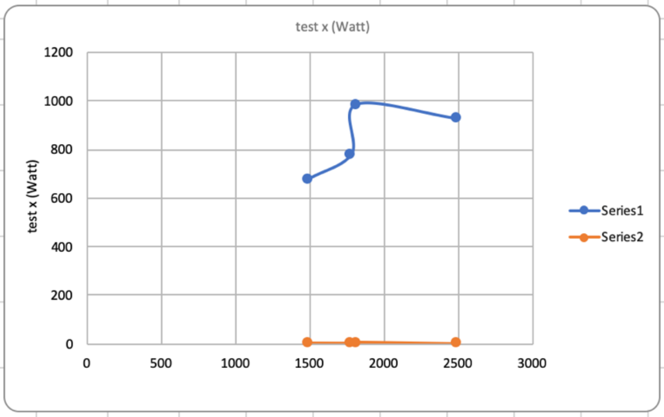
$V = \frac{d^2 \cdot \pi}{4} \cdot h = \frac{1,33^2 \cdot 3,14}{4} \cdot 10 = 13,89\,cm^3$

Fuel consumption: V/time
no load: $\frac{13,89}{34} = 0,409\,cm^3/s$
load-1: $\frac{13,89}{33} = 0,420\,cm^3/s$
load-2: $\frac{13,89}{30} = 0,463\,cm^3/s$
load-3: $\frac{13,89}{38} = 0,366\,cm^3/s$
load-4: $\frac{13,89}{34} = 0,409\,cm^3/s$
Average: $0,4134\,cm^3/s$

Gas mass flow:
Diameter of pipe = 1,33 cm
Height = 10 cm
Area = 44,56 cm^2
Volumetric flow rate, Q = 0,4134 cm^3/s
Average velocity, V = QA
= 0,4134 x 44,56
= 0,1842 m/s
Density of gasoline = 748,9 kg/m^3
Mass flow rate = 748,9 x 0,1842 x 0,0045
= 0,621 kg/s

Power - Torque Curve

Speed motor axis	Power	Torque
test x rpm	test x (Watt)	test x (Nm)
2490	927	3,55
1815	986	5,19
1780	781	4,19
1494	679	4,30



Orange: torque

Blue: Power

7. List of Requirements (Paul)

1. Maximize Power while keeping Reliability
2. Fuel mixture richer
3. Connecting rod shorter
4. Reduce compression rings to 1
5. Increase quality of crankshaft bearings
6. Increase compression ratio of combustion chamber
7. Crankshaft changed from iron to forged steel to make it stronger
8. Flywheel changed to cast iron
9. Reduce pressure in crankcase

8. Conclusion (Paul)

As a group we were able to seek out the best in each group member's capabilities in order to allow each person to feel comfortable in their task, as well as feel that they are contributing to the work needed in order for our group to be able to reach our goal.
Our goal, being that of discovering improvements for our parts that lead to an increase in our motors power. We were able to successfully fulfill this goal through our extensive research into our own parts as well as the engine as à whole; looking at the overall engine allowed us to have à far greater understanding of how our part functioned on its own, in interaction with other parts within, and how our improvements would affect the parts around our given part. After we were able to fully develop our understanding of not only our part, but the engine as well, we then moved on to evaluating data sets and creating new ones through our two labs which opened our eyes to the many sides of an engine. We were able to collect data not only on dimensions, but on our parts hardness, its material, and even the exact types of metals that were contained within it. Each and every data set allowed us to forge à new view on our parts, opening new improvements that could be made while also showing us the possible difficulties which could arise. The labs were à truly good learning experience, allowing for hands on experience that gave us à better sense of what we were dealing with, and where exactly we could take our ideas. Such ideas, that were molded into their best possible outcomes over the course of two weeks, from our initial understanding of what our part could be, to our know full understanding of how our part affects the engine, and how the engine effects it. In the end, our group was able to achieve our goal, of improving the power from subtle to complete overhaul improvements on our individual parts, and because of this; our new found understanding of how each part can affect an engine, we as à group have been able to fully realize and finish our project to the fullest extent; being both in data collected and knowledge gained.

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