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An Experimental Study and Development of Compressed Air Engine in 4 Stroke Single Cylinders

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Now this is not the only reason why we thought about this project. Another big reason is global warming, it's not an individual problem like in previous scenario but it's a global issue it's all about our entire human race's future. These thoughts leads us to a pollution free vehicle concept but as it is very difficult to run a car without degrading it's performance so we searched on internet about fuel which doesn't produce any harmful gases like carbon dioxide, which is mainly responsible for global warming.

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Krishan Kant [α], Pawan Sharma [σ] & Nishant [ρ]

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I. Introduction

A Compressed-air engine is a pneumatic actuator that creates useful work by expanding compressed air. A compressed-air vehicle is powered by an air engine, using compressed air, which is stored in a tank. Instead of mixing fuel with air and burning it in the engine to drive pistons with hot expanding gases, compressed air vehicles (CAV) use the expansion of compressed air to drive their pistons. They have existed in many forms over the past two centuries, ranging in size from hand held turbines up to several hundred horsepower. The laws of physics dictate that uncontained gases will fill any given space. The easiest way to see this in action is to inflate a balloon. The elastic skin of the balloon holds the air tightly inside, but the moment you use a pin to create a hole in the balloon's surface, the air expands outward with so much energy that the balloon explodes. Compressing a gas into a small space is a way to store energy. When the gas expands again, that energy is released to do work. That's the basic principle behind what makes an air car go. Some types rely on pistons and cylinders, others use turbines. Many compressed air engines improve their performance by heating the incoming air, or the engine itself. Some took this a stage further and burned fuel in the cylinder or turbine, forming a type of internal combustion engine.

One manufacturer claims to have designed an engine that is 90 percent efficient. Compressed air propulsion may also be incorporated in hybrid systems, e.g., battery electric propulsion and fuel tanks to recharge the batteries. This kind of system is called hybrid-pneumatic electric propulsion. Additionally, regenerative braking can also be used in conjunction with this system.

II. Components of Compressed Air Engine

Various Mechanical parts used in engine are:

a) Crank shaft
b) Connecting rod
c) Piston cylinder
d) Poppet Valves
e) Roller bearing

a) Crank Shaft

The crankshaft, sometimes casually abbreviated to crank, is the part of an engine which translates reciprocating motion into rotary motion or vice versa. Crank shaft consists of the shaft parts which revolve in the main bearing, the crank pins to which the big ends of the connecting rod are connected, the crank webs or cheeks which connect the crank pins and the shaft parts.

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b) Connecting Rod

Connecting rod is a part of the engine which is used to transmit the push and pull from the piston pin to the crank pin. In many cases, its secondary function is to convey the lubricating oil from the bottom end to the top end i.e. from the crank pin to the piston pin and then for the splash of jet cooling of piston crown. The usual form of connecting rod used in engines has an eye at the small end for the piston pin bearing, a long shank, and a big end opening which is usually split to take the crankpin bearing shells.

The connecting rods of internal combustion engine are mostly manufactured by drop forging. The connecting rod should have adequate strength and stiffness with minimum weight. The materials for connecting rod range from mild or medium carbon steel to alloy steels.

c) Piston Cylinder

A cylinder is the central working part of a reciprocating engine or pump, the space in which a piston travels. Multiple cylinders are commonly arranged side by side in a bank, or engine block, which is typically cast from aluminum or cast iron before receiving precision machine work. Cylinders may be sleeved (lined with a harder metal) or sleeveless (with a wear resistant coating such as Nikasil).

A cylinder's displacement, or swept volume, can be calculated by multiplying its cross-sectional area (the square of half the bore by pi) and again by the distance the piston travels within the cylinder (the stroke). The engine displacement can be calculated by multiplying the swept volume of one cylinder by the number of cylinders.

i. *Poppet Valves*

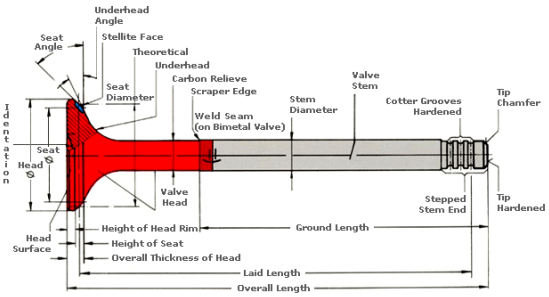
Poppet valves are used in most piston engines to open and close the intake and exhaust ports in the cylinder head. The valve is usually a flat disk of metal with a long rod known as the valve stem attached to one side.

The stem is used to push down on the valve and open it, with a spring generally used to return it to the closed position when the stem is not being depressed. At high revolutions per minute (RPM), the inertia of the spring makes it too slow to return the valve to its seat between cycles, leading to 'valve float'. In this situation desmodromic valves are used which, being closed by a positive mechanical action instead of by a spring, are able to cycle at the high speeds required in, for instance, motorcycle and auto racing engines .

d) Valve

In very early engine designs the valves were 'upside down' in the block, parallel to the cylinders the so called L-head engine because of the shape of the cylinder and combustion chamber, also called 'flathead engine' as the top of the cylinder head is flat. Although this design makes for simplified and cheap construction, it has two major drawbacks; the tortuous path followed by the intake charge limits air flow and effectively prevents speeds greater than 2,000–2,500 RPM, and the

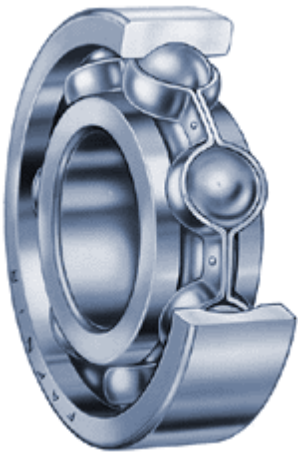
travels of the exhaust through the block can cause overheating under sustained heavy load. This design evolved into 'Intake over Exhaust', IOE or F-head, where the intake valve was in the head and the exhaust valve was in the block; later both valves moved to the head.



e) Roller Bearing

The concept behind a bearing is very simple: Things roll better than they slide. The wheels on your car are like big bearings. If you had something like skis instead of wheels, your car would be a lot more difficult to push down the road. That is because when things slide, the friction between them causes a force that tends to slow them down. But if the two surfaces can roll over each other, the friction is greatly reduced.

Bearings reduce friction by providing smooth metal balls or rollers, and a smooth inner and outer metal surface for the balls to roll against. These balls or rollers "bear" the load, allowing the device to spin smoothly



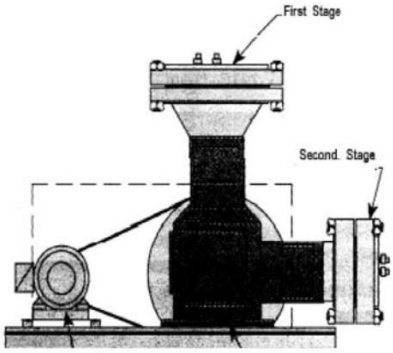
f) Compressor

A gas compressor is a mechanical device that increases the pressure of a gas by reducing its volume. Compressors are similar to pumps: both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas. Liquids are relatively incompressible; while some can be compressed, the main action of a pump is to pressurize and transport liquids.

- *Classification*

Compressors are broadly classified as:

- Positive displacement compressor
- Dynamic compressor



III. Work Undertaken

As the fossil fuels are depleting day by day and burning them is causing a lot of pollution which is resulting into various environmental problems. Therefore, there is a need for a new fuel which is cheap, easy to find, in abundance and most importantly environment friendly. One such source that comes in mind is Air. With this project we will we able to run our vehicles on Air. In this project we are focusing to run 4-stroke engine using Compressed air and in turn cutting down the emission of greenhouse gases. Our main aim is to modify 4-stroke engine so that it can work on compressed air. Compressor is used for producing compressed air and after that compressed air is fed into the engine and pressure energy of compressed air exerts force on piston.

IV. Procedure

We have divided our project in various steps which made it easier for us to work. The various steps are as follows:

a) Collection of materials and components for our project

The project is a combination of different components namely compressor, engine, pressure gauges, pipes, nozzles etc.

Different components were collected by visiting different places during the project development phase. The compressor is available at the thermal lab in the college. Along with the compressor is a cylinder which can store the compressed air at maximum 14 bars. The compressor is a 2 stage reciprocating compressor. A 100cc Hero Honda Splendor engine was bought. A pressure gauge is also installed to control the pressure of the air flowing in the engine. Pipes are used to transfer air into the engine through the inlet valve of the engine via a pressure gauge. A tachometer is arranged from the college lab to read the rpm of the engine.

b) Modification of Camshaft

The camshaft is a very important part of an engine. A camshaft is a shaft to which a cam is fastened or of which a cam forms an integral part. It controls the opening and closing of the inlet and outlet valves so that fuel may enter the cylinder and the exhaust gases may leave the engine cylinder at the correct time. In our project, we have eliminated the use of spark plug.

The camshaft was constructed by joining a part of two different camshafts. Two camshafts were bisected axially with the help of an electric discharge machining (EDM). This task was completed at the NIT, KKR. Electric discharge machining (EDM), sometimes colloquially also referred to as spark machining, spark eroding, burning, die sinking or wire erosion, is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks).Material is removed from the workpiece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the 'tool' or 'electrode', while the other is called the work piece-electrode, or 'workpiece'. The bisected parts of two camshafts were joined together accordingly by gas welding the required parts to form a single camshaft. This camshaft has four lobes and they will work in such a way that the inlet and outlet valves will open and close alternatively in every stroke of the piston in the cylinder.

c) Installation of various components

After the modification of camshaft, this was the most important task in the project; we need to install other components which will work in tandem with each other. The various components to be installed are

- Compressed air cylinder
- Engine with modified camshaft
- Compressor
- Pressure gauge
- Nozzles
- Connecting pipes

i. *Perform Experiments*

After assembling all the components, we run the engine using only compressed air. Now, we have to perform various experiments on the engine. Different tests are performed to find out the efficiency of the engine.

- *Experiment 1*

RPM at different pressures of the compressed air

- *Experiment 2*

Time taken to empty 160 litre capacity tank at different pressure.

V. Fabrication/Development

a) Modification of Camshaft

The camshaft is the most important part of the whole project. Compressed air has to be injected into the cylinder through the inlet valve. As the compressed air is injected into the cylinder of the engine, it starts to expand. This moves the piston in downward direction and the kinetic energy is transferred to the crankshaft. Now, due to inertia of the flywheel, the piston moves in upward direction. This upward motion of the piston ejects the expanded air out of the engine through the exhaust valve. Thus in first stroke injection of compressed air takes place and in the second stroke expanded air is removed from the engine.

Two camshafts were bought. They need to be bisected axially i.e. cut into two pieces through their axes. This cutting is a work of precision as there is very less material to be wasted during cutting. So, to minimise material wastage during cutting, a very efficient method is adopted. The cutting action is performed by Wire Electric Discharge Machine (EDM). Electric discharge machining (EDM), sometimes colloquially also referred to as spark machining, spark eroding, burning, die sinking or wire erosion is a manufacturing process whereby a desired shape is obtained using electrical discharges sparks). Material is removed from the workpiece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the 'tool' or 'electrode', while the other is called the workpiece-electrode, or 'workpiece'.

When the distance between the two electrodes is reduced, the intensity of the electric field in the volume between the electrodes becomes greater than the strength of the dielectric, which breaks, allowing current to flow between the two electrodes. This phenomenon is

the same as the breakdown of a capacitor. As a result, material is removed from both the electrodes. Once the current flow stops (or it is stopped–depending on the type of generator), new liquid dielectric is usually conveyed into the inter-electrode volume enabling the solid particles (debris) to be carried away and the insulating proprieties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as flushing. Also, after a current flow, a difference of potential between the two electrodes is restored to what it was before the breakdown, so that a new liquid dielectric breakdown can occur.

The cutting on EDM gives four pieces from two camshafts. Two pieces are selected from these to form a single camshaft. These two pieces are joined together by gas welding. Welding gives very bad surface finish which if not fixed can cause a lot of vibrations and noise in the engine.

b) Assembling Components

Another important part of the project is the air compressor. For this project, a multi- stage air compressor is used which compresses the air and stores it in a 160 litre cylinder at maximum 10 bars. Multistage compressors are used in place of single stage compressors, because if the compression is done in one stage then the heat generated may be excessive and also material of construction would have to be of very high grade and possibly too expensive. Also power consumption of a single stage compressor would be higher.

The compressor cylinders of these compressors are lubricated with oil and hence the compressed air discharged from the compressor shall always contain traces of oil. Basic principal is that on the suction stroke of the first-stage piston, air at atmospheric pressure enters the cylinder through the inlet filter and valve located in the airhead. On the compression stroke of the first stage piston, the air is compressed to an intermediate pressure and discharged through the valve in to a common manifold. From the manifold, the air passes through the inter-cooler tubes, where the heat of first stage compression is removed by the action of the fan passing cool air over the inter-cooler tubes. On the suction stroke of the second stage piston this cooled air enters the second stage cylinder through the inlet valve. The compression stroke of the second stage piston compresses the air to the final discharge pressure and forces it out through the valve in to the receiver or system.

In a two stage air compressor, the air/gas is compressed to a certain pressure, which would be much lower than ultimately desired pressure in the first stage. This air is then passed through a heat exchanger called 'inter cooler', where the hot compressed air is cooled down, and then the air is further compressed to the final discharge pressure. In compressors where there are more than 2 stages of compression there shall be more than one inter-cooler. Two stage machine are equipped with highly efficient inter cooler tubes that provide maximum heat disperse between stages of compression. If cooling of the discharged air is required, a water-cooled or air-cooled after cooler should be installed between the compressor discharge and the receiver or system.

c) Engine Servicing

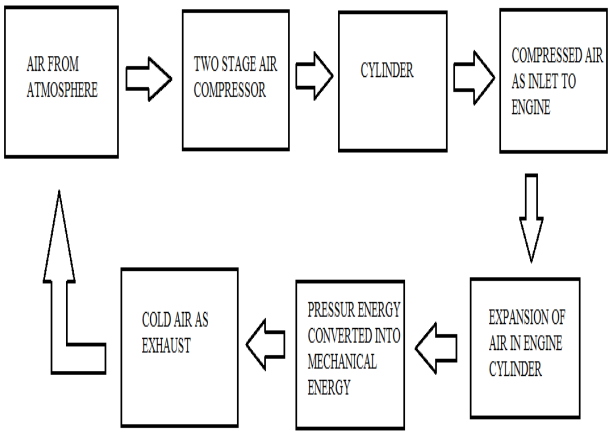
The engine from the previous project is taken and the camshaft is modified to work with compressed air. The engine was not in good shape to be used for this project. Because of this, proper servicing had to done. We overhauled the engine in the thermal lab and cleaned all the parts thoroughly with diesel. The old piston rings were also replaced by new ones as they were not in good shape. The new gaskets were placed to improve the sealing of the engine.

VI. Working of Project

All the components are connected with each other to form a working unit. Compressed Air is released from the cylinder by opening the outlet valve of the cylinder. The pressure can be controlled with the help of the valve. The compressed air moved through the pipe to the inlet of the pressure gauge. The pressure gauge shows the pressure of the air flowing into the engine. The amount of air entering the engine can be controlled by a valve.

When the air reached the inlet valve of the engine, a small amount of momentum need to be given to the flywheel of the engine, this is done by kicking up the engine.

The kick brings the engine to life and the engine keeps running on its own until the compressed air is forced into it. The RPM of the flywheel can be recorded with the help of a tachometer. It can be easily seen that as we increase the pressure of the compressed air supplied to the engine, the engine roars louder i.e. the rotatory speed of the flywheel of the engine is increased.



Working of Compressed Air Engine

VII. Results and Discussion

a) Analysis

This project is Compressed air engine and for experimental work, a 4-stroke engine is used. We have modified the camshaft in such a way that it allows the 4-stroke engine to work as 2-stroke engine. This means there will be one power stroke in one complete rotation of crankshaft. Air is freely available in the atmosphere.

- *According to ideal gas equation*

PV=nRT

Where,

P = Pressure

V = Volume

N = No. of moles

R = Universal Gas constant

T = Temperature

In the above equation, n, R & T are usually taken as constant. From the above equation, it can be seen that volume is inversely proportional to pressure. When the volume of any gas decreases its pressure increases. This means that when air is compressed into a smaller volume its pressure increases. Due to this, a large amount of energy is stored in air as pressure energy. When this compressed air expands, it releases its stored energy which can be used to work. As we have read and studied about Compressed Air, we came to know that it can easily replace other fuels. Moreover, it is more powerful than petrol.

Theoretically, the benefits of using Compressed Air in engine are known but to confirm them, various experiments are conducted. Therefore, experiments are conducted by introducing Compressed Air in the engine at different pressure and corresponding r.p.m of crank shaft is noted. Tests regarding the engine performance are done and also the effects of Compressed Air on the engine components are observed.

The experiments conducted on the engine are as follows:

At Constant Pressure

a) Experiment.1

Readings of Engine Running on compressed air at Constant pressure.

S.No.	Pressure (bar)	RPM		Mean RPM
		Min.	Max.	
1.	2	245	255	250
2.	3	455	465	460
3.	4	565	575	570
4.	5	710	720	715
5.	6	895	905	900

Running the engine on compressed air keeping the Pressure constant

b) Experiment #2

Running the engine on 160 litres capacity compressed air filled cylinder and note its time duration at different pressure.

S.No.	Pressure (bar)	Time (sec)
1.	2	670
2.	3	425
3.	4	332
4.	5	207
5.	6	162

As it has been mentioned earlier that compressed air can replace other fuels. We have modified 4-stroke engine to 2-stroke because air compressor sucks the air from atmosphere and compresses it. So, there is no need of suction and compression stroke separately in the engine. As the compressed air is injected in the engine, it expands and releases the energy stored in the compressed air and

thus pushes the piston from TDC to BDC. Thus completes the power stroke. After that, when the piston moves from BDC to TDC, it ejects the cold air as exhaust to atmosphere.

In this way, 2 stroke cycles is more compatible with compressed air as fuel rather than 4 stroke cycle.

- *According to first experiment*

When we varied the pressure and noted the corresponding RPM, we observed that with the increase in pressure, there is an increase in RPM.

- *According to second experiment*

When we measured the time taken to empty the 160 litre capacity cylinder with respect to different pressure, we observed that with the increase in pressure, the time taken by cylinder to empty decreases.

From the above experiments, we can assume 3 bar as the ideal pressure for running the compressed air engine to obtain ideal RPM. At 10 bar pressure, we obtained 5000 RPM which can run the vehicle at a velocity of around 100 km/hr.

By making certain changes in the engine, we can increase its efficiency and it can be used to drive the vehicles. We can reduce the overall weight of the vehicle and engine by using carbon fibre and aluminium alloys instead of steel parts.

There are always having some benefits and drawbacks of a new technology. This will also have, let's see all of them in brief.

Compressed-air vehicles are comparable in many ways to electric vehicles, but use compressed air to store the energy instead of batteries. Their potential advantages over other vehicles include:

- Much like electrical vehicles, air powered vehicles would ultimately be powered through the electrical grid which makes it easier to focus on reducing pollution from one source, as opposed to the millions of vehicles on the road.
- Transportation of the fuel would not be required due to drawing power off the electrical grid. This presents significant cost benefits. Pollution created during fuel transportation would be eliminated.
- Compressed-air technology reduces the cost of vehicle production by about 20%, because there is no need to build a cooling system, fuel tank, Ignition Systems or silencers.
- Air, on its own, is non-flammable.
- The engine can be massively reduced in size.
- The engine runs on cold or warm air, so can be made of lower strength light weight material such as aluminium, plastic, low friction Teflon or a combination.
- Low manufacture and maintenance costs as well as easy maintenance.
- Compressed-air tanks can be disposed of or recycled with less pollution than batteries.
- Compressed-air vehicles are unconstrained by the degradation problems associated with current battery systems.
- The air tank may be refilled more often and in less time than batteries can be recharged, with re-filling rates comparable to liquid fuels.
- Lighter vehicles cause less damage to roads, resulting in lower maintenance cost.
- Refuelling the compressed-air container using a home or low-end conventional air compressor may take as long as 4 hours though the specialized equipment at service stations may fill the tanks in only 3 minutes.

VIII. Motivation

In recent years, the price of petrol and diesel fuels is going to increase day by day. And the conditions are that vehicles are more and fuel is less. To drive vehicles are not easy for common people. Fuel price hike means that it would grossly affect the calculations that a middle class person has in mind while buying a vehicle. It may be easy to drive vehicles for rich people but not for the poor people.

So, we are working on a project to drive vehicle by using Compressed air. Because air is in abundant amount on earth.

This project will give us benefits as given below:-

i. *No Greenhouse Gas Emissions*

Gasoline and diesel powered vehicles emit greenhouse gases (GHGs) mostly carbon dioxide (CO2), that contribute to global climate change. Compressed air engine is powered by air which emits no GHGs from their tailpipe only cold air.

ii. *Less Air Pollutants*

Highway vehicles emit a significant share of the air pollutants that contribute to smog and harmful particulates in the U.S. CAVs powered by air emit no harmful pollutants.

iii. *Cuts Oil Dependence*

CAV could cut dependence on foreign oil since air can be derived from anywhere; it is a renewable resource. That would make our economy less dependent on other countries and less vulnerable to oil price shocks from an increasingly volatile oil market.

iv. *Increase Engine Life*

No knocking and heat produced therefore it increases engine life.

The engine has injections similar to normal engines, but uses special crank shaft and piston, which remain at TDC for about 70% of the engine's cycle. This allows more power to be developed in the engine.

In normal engine, there is overlapping of inlet and exhaust valves. In 360 degree rotation of crankshaft, the inlet valve remains open for 250 degree and the exhaust valve remains open for 240 degree. Both the valves overlap each other for 120 degree because of which there is a lot of pressure loss. This can be overcome by using solenoid valve which is electronically controlled and is more accurate than mechanical system.

IX. Conclusion

Results obtained by conducting tests on the engine by running the engine on compressed air, we conclude that the compressed air stores energy and that can be utilized for future use. The internal combustion engine is still the predominant means of propulsion, and we have made great strides in reducing its impact on the environment. We have also come a long way in solving the practical problems of electric vehicles, and in developing applications that make full use of their potential. And of course, need leads the world in hybrid technology. Hybrid vehicles have been contributing to a cleaner environment since 1997. Finally, Compressed Air Technology (CAT), which is the zero emission vehicle, may become the ultimate power source of the 21st century. We can use it as an energy storage devices like batteries, fossil fuels etc. It can eliminate batteries in electric cars, fossil fuels from IC engine cars. This will not only lower down monthly fuel costs but also help to put some effort in controlling global warming and many other air pollution issues. After studying various research papers and by this experiment we can conclude that compressed air can be used as fuel in an engine. It does not require cooling system as it produces cool air after expansion in exhaust. Thus, we conclude that this will lower down the maintenance cost of the vehicles which is ultimately beneficial at individual level and also at global level as it will bring down pollution levels.

The compressed air from the storage tank is supplied to the engine. The compressed air which expands in the cylinder moves the piston down. When the piston moves up the exhaust valve opens and the expanded air is pushed out. The linear up and down motion of the piston is converted to the rotary motion of the crank and crank shaft. This is transferred to the wheels by transfer mechanisms.

The output is cooled air. So, no polluting gases are released but only pure air which will help in cutting down the carbon emissions into the atmosphere and in turn bring down the pollution level of air. There is no burning of fuel so no heat is produced, so it helps increase the life of engine. This will give longevity to the life of engine with good performance. The maintenance cost of the complete vehicle will come down with increase in life and no environment polluting emissions.

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