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Design and Developing of Compressed Air Engine

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Abstract - *Internal combustion engine produces a large amount of harmful gases like CO2, SO2 etc. which pollute the environment and causes global warming and it consumes enormous non-renewable energy. So today every country is in search of alternative source of energy and there are couple of alternate source of energy such as solar power, tidal power, geo-thermal power, etc. and one of them is compressed air. The air engine runs on air only, no fossil fuel. The compressed air engine is a modified 100cc conventional engine. The engine is modified from 4-stroke to a 2-stroke engine (suction and exhaust) by modification of cam-gear system. The maximum pressure used is 8 bar. The project was successfully carried out and tested. This technology is cheaper in cost and maintenance and it does not cause any kind of harm to the environment. Thus the compressed air engine will play vital role in reducing air pollution and also in reducing temperature of earth. Compressed air engine uses air as fuel which is available abundantly in atmosphere.*

Key Words: **Compressed Air, Engine, Alternative Source of Energy, Camshaft, Environment.**

1. INTRODUCTION

A compressed air engine, using compressed air, which is stored in a tank, then through the pressure relief valve and buffer tank, it enters the compressed air engine, in which the compressed air pushes the piston to do work and output mechanical energy. Instead of mixing fuel with air and burning it in engine to drive pistons with hot expanding gases, compressed air engine uses the expansion of compressed air to drive their pistons. The compressed air engine is the core dynamic system of air powered vehicles. It is a kind of power device which converts the compressed air energy into mechanical energy by expanding. The piston converts the compressed air into mechanical energy, which is then transferred to the wheels by means of chain sprocket mechanism and used to operate the vehicle. Gas laws explain how compressed air behaves, Boyles law state that if volume of air halves during compression then pressure is doubled. Also, Charles law state that volume of gas changes in direct proportion to temperature. Thus compressed air is used to run the engine by thermodynamic expansion. Energy crisis is due to two reasons, first due to population of world has increased rapidly and second is due to standard of living of every individual. Taking the depletion of fossils fuels, rising petroleum prices, and stringent environmental regulations into consideration, varieties of alternative fuel engine are developing at a rapid pace. Battery electric engine, Fuel cell engine and Hybrid electric engine have been developed. These are just a transitional, not a permanent solution. Because in process of electricity generation, there is still different levels of pollution like carbon emissions depending on the power generation mode, use of battery will cause water and soil pollution during disposal or if it is not properly handled. In comparison with various technology discussed above compressed air technology have many potential advantages like in this technology we use air as fuel and its exhaust is also pure air, here the only pollution source is the process of compressed air generation. And the cost of air compression will be significantly cheaper once the demand of compressed air increases because air is an inexhaustible resource.

2. OBJECTIVE

The main objective is to develop compressed air engine which can be run by the compressed air. A four stroke single cylinder conventional engine can be run on compressed air with a few modifications. Main advantage of compressed air engine is that no hydrocarbon fuel required means no combustion process. Our environment must be protected against various contaminations produced by vehicles driven on I.C. engine which produces some of most adverse environment effects. For example, Nitrogen oxide (NOX) after oxidation forming nitric acid, contributes to acid rain which causes severe damage to environment. Nevertheless, the compressed air technology will contribute to reduce air pollution and tend to zero pollution level and promoting great environment. This is because in compressed air engine air is used as fuel and exhaust is also in the form of air. There are several technical benefits of using this engine, like as no combustion inside cylinder, working temperature of engine is very close to ambient temperature. This in turn results in smooth working of engine, less wear and tear of engine components. There is one more technical benefit that there will not be any need for installing cooling system or complex fuel injection system, etc. These benefits result simple design, simple construction and less weight. Thus compressed air technology satisfies present demand and can prove to be future transport medium.

3. DESIGN OF CAM

In order to develop CAE, we have designed the camshaft with the help of the Unigraphics NX software which is advanced and tightly integrated CAD/CAM/CAE product development solution software. It allows to model solid components and assemblies, to perform engineering analyses, to create tool paths for manufacturing processes and to perform numerous other engineering design activities in single software.

3.1 Design Procedure

To start designing process, open NX software. it may take few minutes to open. Once opened, Unigraphics welcome page be presented on the window screen shown in Fig 1.

Fig -1: Unigraphics NX welcome page

To create a new file, click on the 'New' tab on the top of screen, and create part file to start modeling. NX part file uses the extension ·Prt for both components and assemblies of components.

After this new session will be open, asking for name and location of the new file to be created. Here you need to select the units (inches or millimeters) as shown in Fig 2.

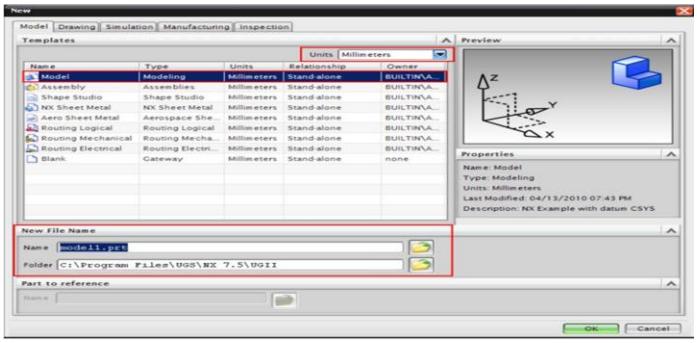

Fig -2: Save As tab

Once new file has been created, NX modeling interface tab will be open. Like most modern PLM tools, this interface contains numerous icons, lists, text prompts and other features. As shown in Fig 3 the tab contains sketching tools, part navigator, viewer and menu.

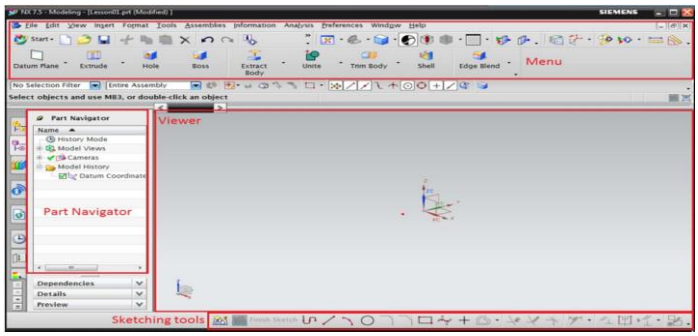

Fig -3: Unigraphics NX modeling interface

2D drawing of CAM of conventional engine and compressed air engine (modified engine) with all the required dimensions and GD&T representations suits the best for manufacturing the component without any error is used to design 3D model for component.

To draw first click on insert in menu ribbon and select Task Environment, select plane. Then by using curves like line, circle, arc, profile, offset curve, quick trim, fillet etc. from sketching tools draw 2D design of CAM.

After Drawing 2D diagram of CAMs extrude command is to be used to create a body sweeping a 2D or 3D section of curves, edges, sketches in a specified direction. To convert 2D in 3D click on insert, design features and then on extrude option. Select the curves, specify vector select Boolean operation (unite, subtract, intersect) then click on ok.

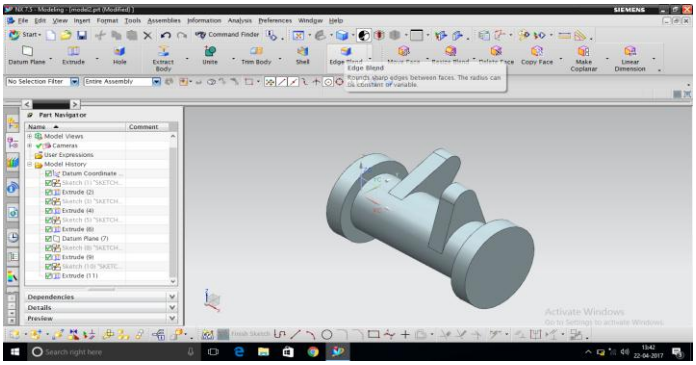

Fig -4: Cam design of convention engine

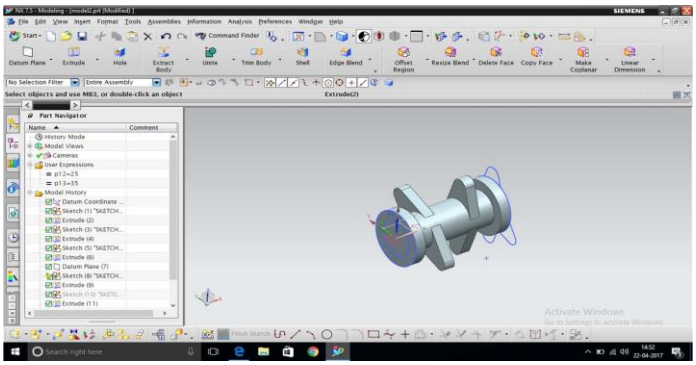

Fig -5: Cam design of compressed air engine

4. MODIFICATION OF CONVENTIONAL ENGINE

The 4-stroke conventional engine camshaft cannot be used in compressed air engine to run it. Thus we convert camshaft of 4-stroke into 2-stroke with slight modifications in it and valve timing ratio. Before modification shape of lobes of cam was v-shaped, after modification it is converted to I-shaped i.e. the inlet and exhaust at 180°. Also for continuous supply of air, to generate more torque we shaped oval shape at lobes CAM to the individual side through 180°.

Valve is used to regulate the flow of air fuel mixture inside the cylinder and exhaust gas outside the cylinder. Hence the valve timing ratio is also to be change to 1:1 instead of 2:1, so for every revolution of crankshaft the camshaft will rotate once.

4.1 Step Involved in Modification

With the help of arc welding, arc welding is to be on the opposite sides of two lobes which already exists and grinding is to be done to get the exact oval shape or I-shaped lobes. After this machining process

Fig -6: Arc Welding Process

Fig -7: Grinding process

Fig -8: Adjusting Valve timing

5. LAYOUT OF CAV

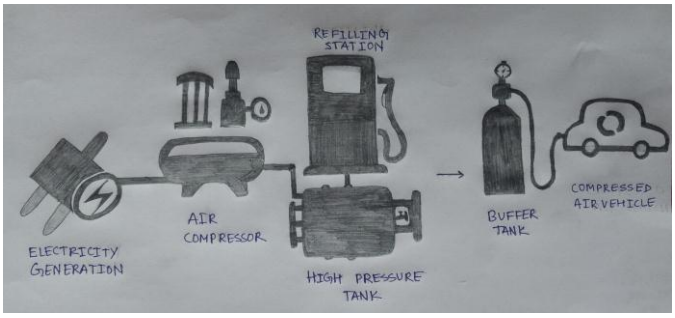

Fig -9: Systematic layout of CAV

As shown in Fig 8 at refilling station, high pressure tank is installed with heavy air compressor which can produce huge amount of compressed air to match the requirement of demand of consumers. Air compressor is powered by electricity. In this it is clearly shown that transportation of fuel is not require because every refilling station can produce compressed air of their own and can sell it to consumers. In compressed air vehicle there is buffer tank which can be refilled at any refilling stations.

5.1 Components of CAV

Fig -10: Prototype of compressed air engine

1. Storage tank: In order to use compressed air engine in vehicles for transportation purpose, high pressure storage cylinder is used to store the compressed air. Therefore, the storage system must be compact and lightweight. Generally, the cylinder is fitted with stop valve. The valve also includes a pressure relief device.

2. Pressure regulator: A pressure regulator is used to regulate the pressure of compressed air in the storage cylinder to working pressure of the engine.
3. Pressure gauge: It is an instrument used to measure the pressure of fluid. It is installed before inlet valve to measure the pressure of inlet air.
4. Hoses and Fittings: Hoses are used for carrying compressed air from storage cylinder to the engine. Hoses are made from one or combination of many different materials. Polytetrafluoroethylene (PTFE) hoses are preferred because it is chemically inert and usable at temperature ranging from -70°C up to +260°C.
5. Air engine: A 4-stroke convention IC engine of 100cc is converted in compressed air engine after modifying camshaft and valve timing.
6. Frame: It is structure on which all other components will be installed. This should have simple and easy construction.

6. ENGINE SPECIFICATION

Conventional engine is 4-stroke I.C engine without any modification.

Table -1: Engine Specification

Specification of Conventional Engine	
Model	Hero Honda CD 100 SS
Engine Displacement	97.2 CC
Engine Type	Air cooled, 4 Stroke
Number Of Cylinders	1
Valves Per Cylinder	2
Fuel Type	Petrol
Starter	Kick
Number of Stroke	4 Stroke
Transmission Type	Manual
Number Of Speed Gears	4

Compressed air engine is modified engine which is converted from conventional 4-stroke engine after modification. In this type of engine old camshaft is modified and installed in it and valve timing is arranged according to new modified cam. So in both case specification of engine is same. But in compressed air engine fuel type is compressed air, there is no ignition and number of stroke is 2 (suction and exhaust).

7. WORKING OF ENGINE

7.1 Working of Conventional Engine

A four-stroke engine is an IC engine in which the Piston completes four strokes. A stroke refers to the full travel of the piston along the cylinder, in either direction. The four strokes are as follow:

1. SUCTION
2. COMPRESSION
3. EXPANSION
4. EXHAUST

1. SUCTION: In this stroke, the piston descends from the Top Dead Centre of the cylinder to the Bottom Dead Centre of the cylinder, increasing the volume of the cylinder. A mixture of fuel and air is forced by atmospheric or greater pressure into the cylinder through the intake valve.
2. COMPRESSION: In this stroke, both intake and exhaust valves are closed, the piston returns to the top of the cylinder compressing the air or fuel-air mixture into the cylinder head.
3. EXPANSION: Expansion stroke is the start of the second revolution of the cycle. In this stroke, the piston is close to Top Dead Centre, the compressed air–fuel mixture in a gasoline engine is ignited, by a spark Plug in gasoline engines, or ignites due to the heat generated by compression in a petrol engine. The resulting pressure from the combustion of the compressed fuel-air mixture forces the piston back down toward Bottom Dead Centre.
4. EXHAUST: During the exhaust stroke, the piston once again returns to Top Dead Centre while the exhaust valve is open. This action expels the spent fuel-air mixture through the exhaust valve.

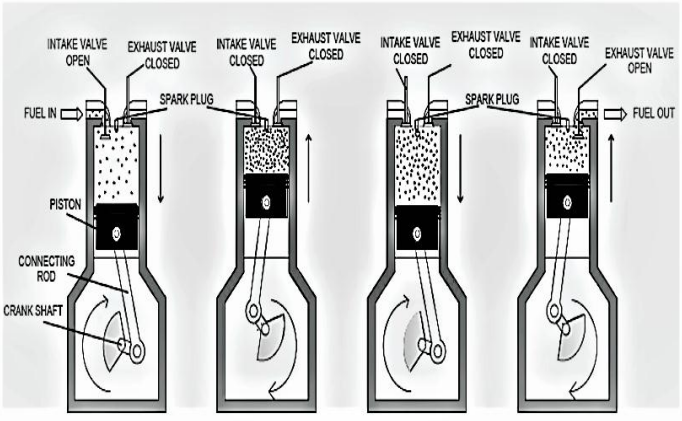

Fig -11: Cycle Stroke of 4-Stroke Engine

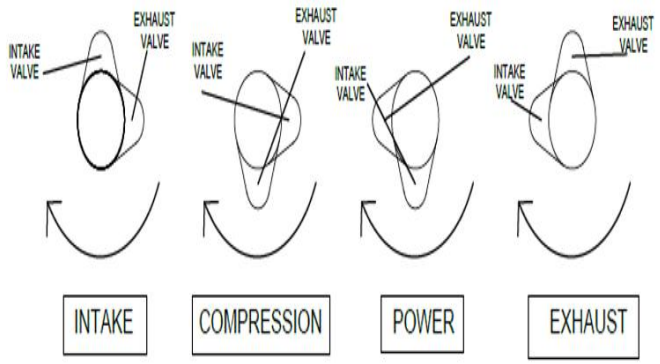

Fig -12: Cam Profile of 4-Stroke Engine

7.2 Working of CAE

In compressed air engine the working mechanism is partially similar with conventional 4-stroke engine. But, yet it has only two stroke that is

1. POWER STROKE
2. EXHAUST STROKE

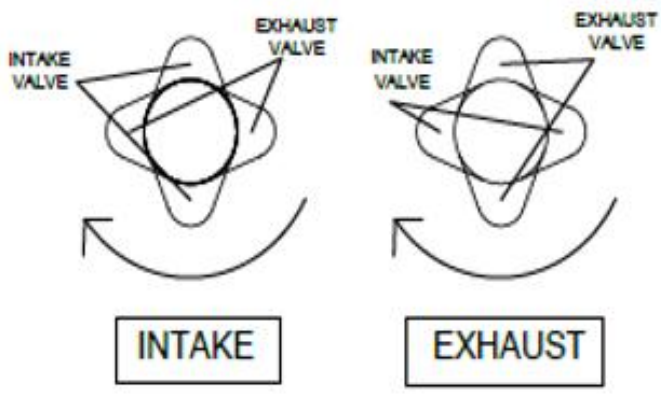

Fig -13: Cam Profile of Compressed Air Engine

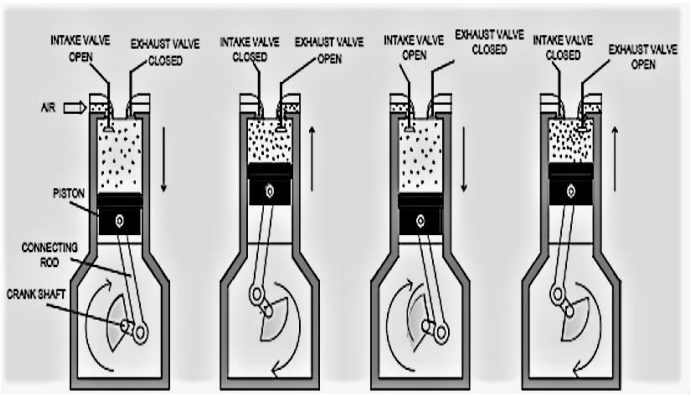

Fig -14: Cycle Strokes of Compressed Air Engine

1. POWER STROKE: Power stroke is suction stroke or Intake Stroke, in this stroke when the piston is at the top position (TDC) its spindle opens the inlet valve, the compressed air fills the space of cylinder. The air expands and exerts pressure on the surface of piston, causing its movement down to BDC.
2. EXHAUST STROKE: In exhaust stroke of CAE, air escape from cylinder through exhaust valve and inlet valve get closed. One interesting benefit is that the exhaust air temperature of CAE measured practically as low as 17.6°C is less than atmospheric temperature, helps in reducing the temperature and controlling global warming rise caused by I.C engines or due to other means. In the cylinder are small amounts of air, so the piston moves upwards until it will again open the ball valve and the cycle repeats.

8. VALVE TIMING DIAGRAM

The valve timing is the precise timing of the opening and closing of the valves. In 4-stroke engines and 2-stroke engines, the valve timing is controlled by the camshaft. It can be varied by modifying the camshaft, also by the adjustment of the valve mechanism.

8.1 Valve Timing of Conventional Engine

As shown in Fig.12 the actual valve timing diagram, the inlet valve is opened 10° to 30° in advance of the T.D.C position to enable the fresh charge to enter the cylinder and to help the burn the gases at the same time, to escape to the atmosphere. The suction of the mixture continues up to 30°-40° or even 60° after the piston reaches BDC position.

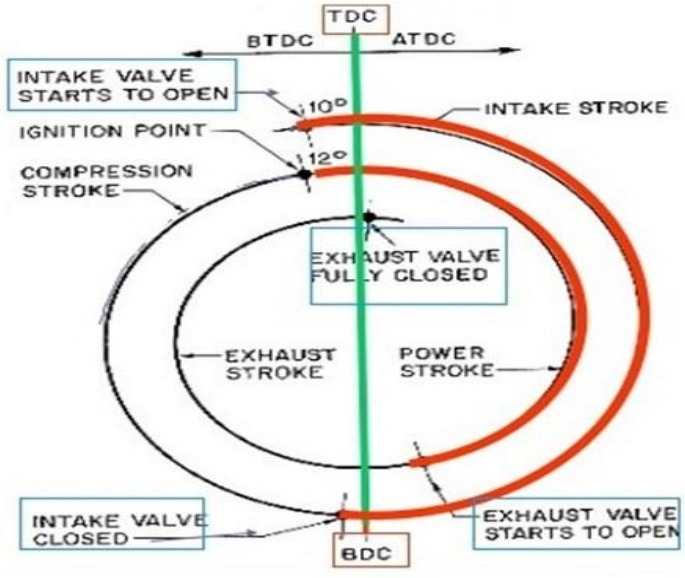

Fig -15: Valve Timing Diagram of Conventional Engine

The inlet valve closes and the compression of the entrapped mixture starts. The sparking plug produces a spark 30° to 40° before the TDC position thus fuel gets more time to burn. The pressure becomes maximum nearly 10° past the TDC position. The exhaust valve opens 30° to 60° before the BDC position and the gases are driven out of the cylinder by position during its upward movement. The exhaust valve closes when piston is nearly 10° past TDC position and this process of movement of piston continues.

8.1 Valve Timing of Compressed Air Engine

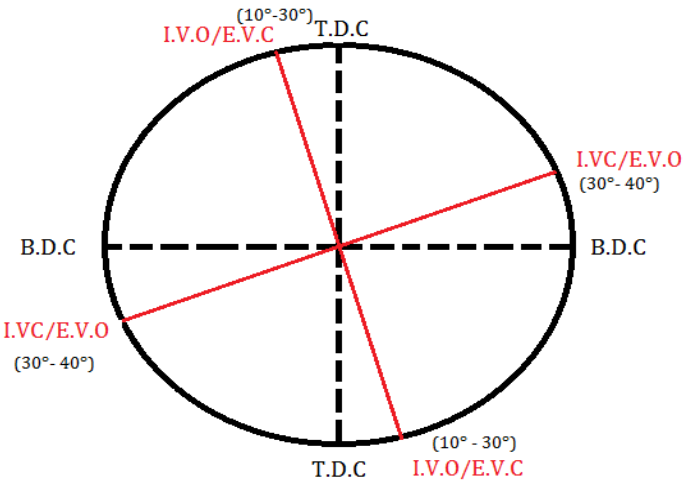

Fig -16: Valve Timing Diagram of Compressed Air Engine

As shown in Fig.13 the actual valve timing diagram, the inlet valve is opened 10° to 30° in advance of the T.D.C position to enable the compressed air to enter the cylinder. The suction of the compressed air continues up to 30°-40° or even 60° after piston reaches BDC position. The inlet valve closes and exhaust valve opens hence there is no combustion cycle process in compressed air engine, it eliminates the compression and expansion cycle. The exhaust valve opens 10° to 30° before the BDC position and the compressed air is driven out of the cylinder by position during its upward movement. The exhaust valve closes when piston is nearly 10° past TDC position and the process continues.

9. EXPERIMENTAL ANALYSIS AND RESULTS

The power outputs from the modified air engine were measured at air pressure ranging from 1 to 5 bar. Chart 1,2,3,4 is the result of pressure and speed at gear 1,2,3,4 respectively. In this experiment, it has been found that if the cam lobes in conventional engine of 4stroke engine is modified and timing valve ratio is changed then the conventional engine can be converted into air engine. Thus the performance of CAE mainly influenced by air supply pressure. The prototype of CAE has good performance under low speed. Air powered vehicle is a realization of latest technology in automobile field tend to healthier environment.

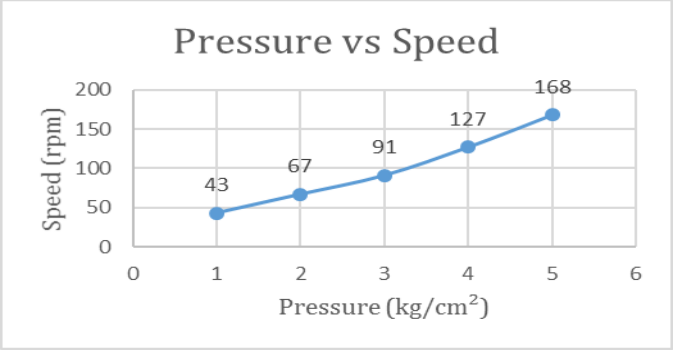

Chart -1: Pressure vs Speed (1st Gear)

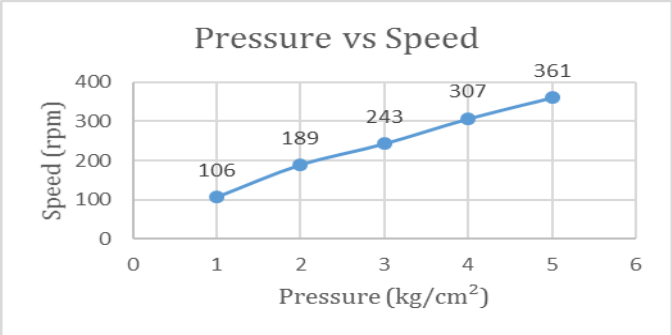

Chart -2: Pressure vs Speed (2nd Gear)

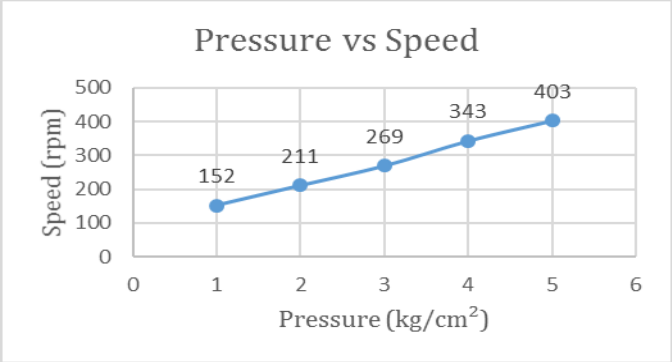

Chart -3: Pressure vs Speed (3rd Gear)

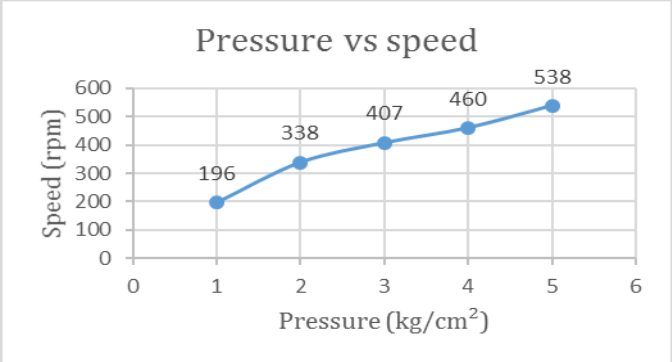

Chart -4: Pressure vs Speed (4th Gear)

From the above graph we conclude that the speed of vehicle depends on pressure I.e., if pressure increases then speed increases and vice-versa but maximum pressure should not exceed 8 bar and for precaution we should not increase pressure more than 5 bar.

9.1 Economic Benefits

1. No use of expensive fossil fuels as the free air is compressed and taken to use.
2. Compressors use electricity for generating compressed air which is relatively much cheaper and widespread.
3. Smooth working will lead to less wear & tear, so lesser maintenance cost.
4. Compressed air is most sustainable. It has no volatility or temperature or much weather effect.

Once compressed air is stored through compressor, it will be available at any time without any loss of Pressure.

9.2 Technical Benefits

Air Powered Engine is an alternative technology which uses compressed air to run the engine and thus eliminates the use of fossil fuels. Exhaust temperature of it will be slightly less than atmospheric temperature (i.e. 20-25°C) and thus helps in controlling global warming and reducing temperature rise caused due to other means. As we are going to convert the already existing conventional engine into an air powered one, this new technology is easy to adapt. Another benefit is that it uses air as fuel which is available abundantly in atmosphere.

Apart from above other technical benefits are as follows:

1. The temperature of the engine while working will be slightly less than the ambient temperature.
2. Smooth working of the engine due to very less wear and tear of the components.
3. No need of cooling systems and spark plugs or complex fuel injection systems.

9.3 Environmental Benefits

Compressed air may be definitely as an alternate for running light vehicle, which is presently creating emission due to use of fossil fuel and ultimately effects public health hazard. The major benefits of Air Engine for environmental safety are:

1. As the exhaust temperature of this engine will be slightly less than the atmospheric temperature (i.e. 15-25oC). So this will help in cooling the environment.
2. If this technology is widely used than it will help in controlling global warming. These are some green bytes associated with this technology.
3. Exhaust gases leaving the engine will be only air having low temperature. So this will eliminate the problem of harmful emissions, in conventional engines. This gives us environmental benefit of using this engine.

10. CONCLUSIONS

The conventional engine used is being subjected to modifications like camshaft modification and timing valve arrangement. The old cam is modified with a profile such that for one cycle of piston movement inlet and outlet valve opens and closes as required in compressed air engine. Compressed air is non-conventional energy and it is abundant in nature which will exist till sun in universe. Due to global warming it is demand of time to adopt green technology.

11. FUTURE SCOPE

Further study is to be done to improve the performance parameters like output and efficiency. Compressed Air Engine will be make revolution in automobile industry. This engine having many advantages than the conventional engines. With some modifications it will give better performance than the conventional engines. This engine having minimum disadvantages. It is cheaper than any other technology. So in future compressed air engine will be give the better option for the conventional engines.

Few advancements in this presented project can be taken up by doing some ideal methods like:

1. As there is no combustion use of lighter engine parts like carbon fiber for piston and connecting rod will give more efficiency as inertia will decrease.
2. Installing of external heater to heat inlet air before entering the engine can improve the efficiency.
3. Develop cylinders with lesser weight and less volume and a capacity to store high pressure.
4. Making the chassis light weight by selecting proper materials can also greatly affect the efficiency of the CAV.

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