Research Paper Engineering

Development and Testing of Compressed Air Driven Vehicle

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ABSTRACT

Light utility vehicles are becoming very popular means of independent transportation for short distances. Cost and pollution with petrol and diesel are leading vehicle manufacturers to develop vehicles fueled by alternative energies.
Engineers are directing their efforts to make use of air as an energy source to run the light utility vehicles. The use of compressed air for storing energy is a method that is not only efficient and clean, but also economical.
Problem with the engine is the due to the lack of "torque" produced by engine. Many companies are still finding out the methods to overcome the initial losses of the engine and reduce the cost and increase the benefits of the compressed air.
Air contains moisture that needs to be reduced hence the incoming moisture in the engine reduces its efficiency.
The air inclusion into the cylinder by the compressor is a polytropic process but it needs to be isothermal in order to reduce the compressor work.
It has zero emissions and is ideal for city driving conditions. Although it seems to be an eco-friendly solution, one must consider its well to wheel efficiency.

KEYWORDS Compressed air, valve timing diagram, minimum pressure required Environmental problem.

Introduction

A compressed air vehicle is the vehicle which completely runs on compressed air. There is no need of fuel or gasoline. It follows the first law of thermodynamics. When air is compressed it stores energy in the form of pressure this energy is converted into mechanical energy when air expands into the cylinder[1] .A compressed-air vehicle (CAV) 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 use the expansion of compressed air to drive their pistons. We are living in a very mobile society so light utility vehicles (LUV) like bikes and cars are becoming very popular means of independent transportation for short distances. Petrol and diesel which have been the main sources of fuel in the history of transportation are becoming more expensive and impractical (especially from an environmental standpoint). Such factors are leading vehicle manufacturers to develop vehicles fuelled by alternative energies. When at present level of technological development fuel-less flying (like birds) i.e., flying based on the use of bio-energy and air power in the atmosphere Seems to be almost impossible for human beings then engineers are fascinated at least with the enormous power associated with the human friendly as well as tested source of energy (i.e., air) to make compressed air vehicles as one possible alternative[2] . Engineers are directing their sincere efforts to make use of air as an energy source to run the LUVs which will make future bikes and light/small cars running with air power for daily routine distances and the travel will be free from pollution and cost effective.

The Basic Structure

Following is the detail of basic structure of compressed air vehicle:

1. Ladder Frame Chassis- Ladder frame chassis is also known as body-on-frame chassis. Body-on-frame is an automobile construction method. Mounting a separate body to a rigid frame that supports the drivetrain was the original method of building automobiles, and continues to this day[3]. Originally frames were made of wood (commonly ash), but steel ladder frames became common in the 1930s. It is technically not comparable to newer unibody designs, and almost no modern vehicle uses it (other than trucks).

Typically the material used to construct vehicle chassis and frames is carbon steel; or aluminum alloys to achieve a more light-weight construction. In the case of a separate chassis, the frame is made up of structural elements called the ***rails*** or ***beams***. These are ordinarily made of steel channel sections, made by folding, rolling or pressing steel plate.

Figure: Ladder frame chassis

2. Rack and pinion- A rack and pinion is a type of linear actuator that comprises a pair of gears which convert rotational motion into linear motion. A circular gear called "the pinion" engages teeth on a linear "gear" bar called "the rack"; rotational motion applied to the pinion causes the rack to move relative to the pinion, thereby translating the rotational motion of the pinion into linear motion.

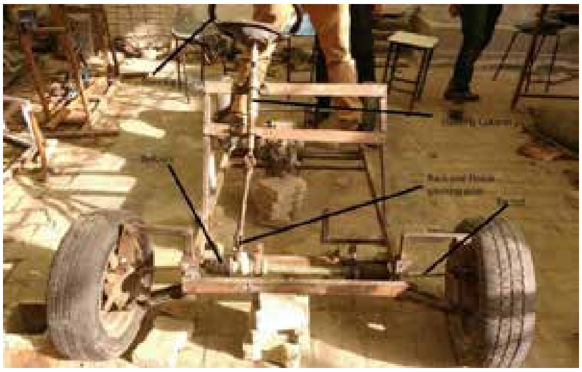

Figure: Rack and Pinion Steering System

3. Macpherson strut suspension system- The MacPherson strut is a type of car suspension system which uses the top of a telescopic damper as the upper steering pivot. It is widely used in the front suspension of modern vehicles and is named for American automotive engineer Earle S. MacPherson, who originally invented and developed the design.

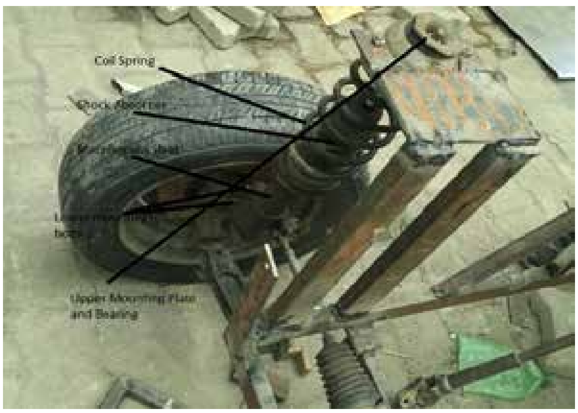

Figure: Macpherson Strut Suspension System

4. Chain and sprocket arrangement- Chain drive is a way of transmitting mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles. It is also used in a wide variety of machines besides vehicles. Though drive chains are often simple oval loops, they can also go around corners by placing more than two gears along the chain; gears that do not put power into the system or transmit it out are generally known as idler-wheels. Sprockets are used in bicycles, motorcycles, cars, tracked vehicles, chainsaws and other machinery either to transmit rotary motion between two shafts where gears are unsuitable or to impart linear motion to a track, tape etc.

Figure: chain and sprocket

5. Rear wheel drive- Rear-wheel drive (RWD) typically places the engine in the front of the vehicle and the driven wheels are located at the rear, a configuration known as front engine, rear-wheel drive layout (FR layout). The front mid-engine, rear mid-engine and rear engine layouts are also used. Nearly all motorcycles and bicycles use rear-wheel drive as well, either by driveshaft, chain, or belt, since the front wheel is turned for steering, and it would be very difficult and cumbersome to "bend" the drive mechanism around the turn of the front wheel[5]. A relatively rare exception is with the 'moving bottom bracket' type of recumbent bicycle, where the entire drive-train, including pedals and chain, pivot with the steering front wheel.

Modifications

Following are the modifications made in the Compressed air vehicle:

1. Changes with the intake port- To use compressed air as input, intake port is to be change. Intake port should be in favor of air. Air comes from air storage tank through a pipe of 8 mm inner diameter. So there are some changes are done to take the air as input [6] .

Figure: Modification in the intake port

2. Valve timing diagram- Valve timing of engine depends upon cam angle, timing chain and sprocket. The angle of cam is 180° it means when intake valve open exhaust valve will be close and vice a versa. When piston will come from TDC to BDC, intake valve open after 15° rotation of crank from TDC. And close before 35° from BDC. In this stroke air expands and creates force on piston. When piston moves from BDC to TDC exhaust valve open after 20° from BDC and closes before 35° from TDC. In this stroke pushed off from cylinder. Similarly cycle repeats in next rotation.

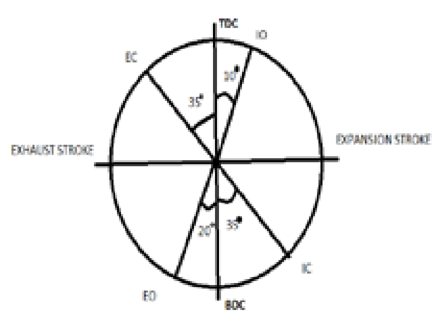

Figure: Valve timing diagram

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3. Timing chain- To maintain the gear ratio 1:1 for valve timing we have to reduce diameter of big sprocket equal to small sprocket. It means distance between end points of sprockets is reduced. So we have to cut the timing chain.

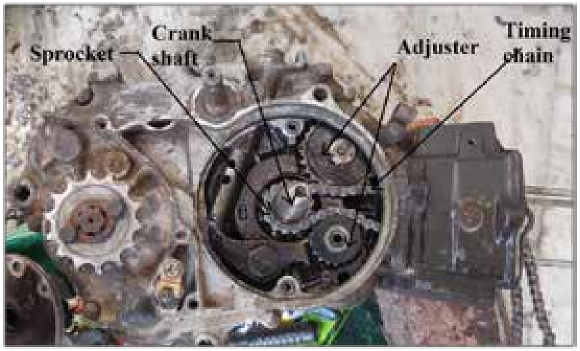

Figure: Exploded view of engine Timing chain

4. Cam shaft- Camshaft is use for opening and closing of valves. When piston goes down inlet valve should open, and when piston comes towards TDC exhaust valve should be open and inlet valve should be close. It means the angle of cam should be 180°, and should have same gear ratio.

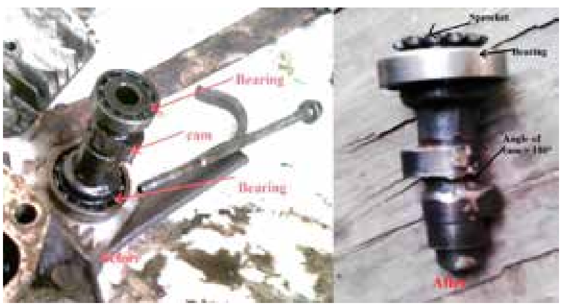

Figure: Changes made with the cam

Working-

Compressed air vehicle runs on compressed air instead of gasoline. Since the vehicle is working on air there is no pollution. A single cylinder, compressed air engine, powers the vehicle. The engine can run either on compressed air alone or act as an internal combustion engine. Compressed air is stored in fiber or glass fiber tanks at a pressure of 4000 pounds per square inch. The air is fed through an air injector to the engine and flows into a small chamber, which expands the air. The air pushing down on the piston moves the crankshaft, which gives the vehicle power.

Pressure required to run the vehicle
Mass of the body = 50kg
Mass of the cylinder = 90kg
Mass of the engine = 20kg
Mass of human = 70kg
Total mass will be = 230kg
Approximately we take it as mass = 250kg
Gravitational acceleration = 9.8 m/s^2 (10 m/s^2 approx.)
Weight of the vehicle = mass * gravitational acceleration
= 250 * 10
=2500 N
=2.5 KN

This is the vertical force acting on the wheel in the direction of gravity.

Force required to run the vehicle should be greater than the resisting force on the wheel. This resisting force is the friction force between wheel and road surface. So we have to calculate this friction force on the wheel.

Friction force (F) = μ×N

Where μ is coefficient of friction

N is normal reaction force which is equal to the vertical force.
F = =.0.3×2500

750 N

Resisting torque on wheel (τ_R) = ***f* • *R***

The net torque causes angular acceleration on wheel (τ) = $\tau_e - \tau_R$

Where; τ_e is the torque applied by engine

$\tau = I \bullet \alpha$

$\tau_e - \tau_R = I \bullet \alpha$

$\tau_e = \tau R + I \bullet \alpha$

$= f \bullet R + \frac{1}{2} m R^2 * f/mR \qquad \{\alpha = f/mR$

$\tau_e = 3fR/2$

We know that

f = 750 N

R = 200 mm = 0.2 m

$\tau_e = 3 \times 750 \times 0.2/2$

= 225 N-m

We can take it as 250 N-m because there are many unnecessary forces which are acts in actual practice like friction force

τ_e = 250 N-m

Gear ratio in first gear is 2.71, it means

Torque on output shaft of engine/torque on crank = 2.71

Torque on crank shaft = $\tau_e/2.71$

225/2.71

=83.02 ≈ 83 N-m

To rotate crank shaft 83 N-m torque is required. This torque can be balanced by the force applied by the piston F_p.

F_p = torque / radius of crank

F_p = 83/0.04

F_p = 2075 N

Pressure = Force /Area

Area of piston = $(\pi/4) \times d^2$

Area of piston = 2.29×10^{-3} m^2

	Pressure = $2075/2.29\times10^{-3}$
	= 906.113 KN/m^2
Or	= 9.061 bar
Or	= 131.42 PSI

This is the minimum pressure required to run the vehicle having 2.5 KN weight. So we require the higher pressure than we calculated to run vehicle at high speed.

Possible improvements

Compressed-air vehicles operate to a thermodynamic process as air cools down when expanding and heats up when being compressed. As it is not possible in practice to use a theoretically ideal process, losses occur and improvements may involve reducing these, e.g., by using large heat exchangers in order to use heat from the ambient air and at the same time provide air cooling in the passenger compartment. At the other end, the heat produced during compression can be stored in water systems, physical or chemical systems and reused later. It may be possible to store compressed air at lower pressure using an absorption material within the tank. Absorption materials such as Activated carbon, or a metal organic framework is used to store compressed natural gas at 500 psi instead of 4500 psi, which amounts to a large energy saving[7].

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