

Compressed Air Engine

SwadhinPatnaik

Dept. of Mechanical engineering, SRM University, Chennai, India

Abstract

This paper work deals with the Compressed-air engine as a pneumatic actuator that converts one form of energy into another. The Air Driven Engine is an eco-friendly engine which operates with compressed air. This Engine uses the expansion of compressed air to drive the pistons of the engine. An Air Driven Engine is a pneumatic actuator that creates useful work by expanding compressed air. There is no mixing of fuel with air as there is no combustion. An Air Driven Engine makes use of Compressed Air Technology for its operation The Compressed Air Technology is quite simple. If we compress normal air into a cylinder the air would hold some energy within it. This energy can be utilized for useful purposes. When this compressed air expands, the energy is released to do work. So this energy in compressed air can also be utilized to displace a piston. 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.

Keywords

Air, Compressed, Engine, Energy, Propulsion, Pneumatic

I. Introduction

At first glance the idea of running an engine on air seems to be too good to be true. Actually, if we can make use of air as an aid for running an engine it is a fantastic idea. As we all know, air is all around us, it never runs out, it is non-polluting and it is free.

An Air Driven Engine makes use of Compressed Air Technology for its operation. Compressed Air Technology is now widely preferred for research by different industries for developing different drives for different purposes. The Compressed Air Technology is quite simple. If we compress normal air into a cylinder the air would hold some energy within it. This energy can be utilized for useful purposes. When this compressed air expands, the energy is released to do work.

So this energy in compressed air can also be utilized to displace a piston. This is the basic working principle of the Air Driven Engine. It uses the expansion of compressed air to drive the pistons of the engine. So an Air Driven Engine is basically a pneumatic actuator that creates useful work by expanding compressed air. This work provided by the air is utilized to supply power to the crankshaft of the engine.

In the case of an Air Driven Engine, there is no combustion taking place within the engine. So it is non-polluting and less dangerous. It requires lighter metal only since it does not have to withstand elevated temperatures.

As there is no combustion taking place, there is no need for mixing fuel and air. Here compressed air is the fuel and it is directly fed into the piston cylinder arrangement. It simply expands inside the cylinder and does useful work on the piston. This work done on the piston provides sufficient power to the crankshaft

II. Components

- CYLINDER
- PISTON
- COMBUSTION CHAMBER
- ONNECTING ROD
- CRANKSHAFT
- CAMSHAFT
- CAM
- PISTON RINGS
- GUDGEON PIN
- INLET
- EXHAUST MANIFOLD
- INLET AND EXHAUST VALVE
- FLYWHEEL

III. Engine Specifications

| | | |
|--------------------|---|-------------|
| Type of fuel used | : | Petrol |
| Cooling system | : | Air cooled |
| Number of cylinder | : | Single |
| Number of stroke | : | Four Stroke |
| Arrangement | : | Vertical |
| Cubic capacity | : | 100 cc |

IV. Layout of the Project

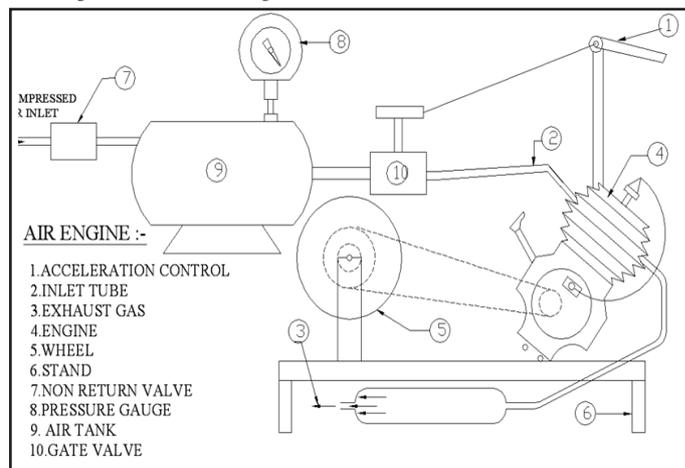


Fig. 1: Layout of the Project

V. Compressed Air Engine Principle

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. 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.

A. Engine

A Compressed-air engine is a pneumatic actuator that creates useful work by expanding compressed air. They have existed in

many forms over the past two centuries, ranging in size from hand held turbines up to several hundred horsepower. Some types rely on pistons and cylinders, others use turbines.

Many compressed air engines improve their performance by heating the incoming air, or the engine itself. Some took this a stage further and burned fuel in the cylinder or turbine, forming a type of internal combustion engine. One can buy the vehicle with the engine or buy an engine to be installed in the vehicle. Typical air engines use one or more expander pistons. In some applications it is advantageous to heat the air, or the engine, to increase the range or power.

B. Tank

The tanks must be designed to safety standards appropriate for a pressure vessel, such as ISO 11439.

The storage tank may be made of:

1. Steel,
2. Aluminium,
3. Carbon fiber,
4. Kevlar,
5. Other materials or combinations of the above.

The fiber materials are considerably lighter than metals but generally more expensive. Metal tanks can withstand a large number of pressure cycles, but must be checked for corrosion periodically. One company stores air in tanks at 4,500 pounds per square inch (about 30 MPa) and hold nearly 3,200 cubic feet (around 90 cubic metres) of air.

The tanks may be refilled at a service station equipped with heat exchangers, or in a few hours at home or in parking lots, plugging the car into the electrical grid via an on-board compressor.

C. Compressed Air

Compressed air has a low energy density. In 300 bar containers, about 0.1 MJ/L and 0.1 MJ/kg is achievable, comparable to the values of electrochemical lead-acid batteries. While batteries can somewhat maintain their voltage throughout their discharge and chemical fuel tanks provide the same power densities from the first to the last litre, the pressure of compressed air tanks falls as air is drawn off. A consumer-automobile of conventional size and shape typically consumes 0.3-0.5 kWh (1.1-1.8 MJ) at the drive shaft per mile of use, though unconventional sizes may perform with significantly less.

D. Emission Output

Like other non-combustion energy storage technologies, an air vehicle displaces the emission source from the vehicle's tail pipe to the central electrical generating plant. Where emissions-free sources are available, net production of pollutants can be reduced. Emission control measures at a central generating plant may be more effective and less costly than treating the emissions of widely-dispersed vehicles.

Since the compressed air is filtered to protect the compressor machinery, the air discharged has less suspended dust in it, though there may be carry-over of lubricants used in the engine.

6. Working Principle

Today, internal combustion engines in cars, trucks, motorcycles, aircraft, construction machinery and many others, most commonly use a four-stroke cycle. The four strokes refer to intake, compression, combustion (power), and exhaust strokes that occur during two crankshaft rotations per working cycle of the gasoline

engine and diesel engine.

The cycle begins at Top Dead Center (TDC), when the piston is farthest away from the axis of the crankshaft. A stroke refers to the full travel of the piston from Top Dead Center (TDC) to Bottom Dead Center (BDC).

A. INTAKE stroke

On the intake or induction stroke of the piston, the piston descends from the top of the cylinder to the bottom of the cylinder, reducing the pressure inside the cylinder. A mixture of fuel and air is forced by atmospheric (or greater) pressure into the cylinder through the intake port. The intake valve(s) then close.

B. COMPRESSION stroke

With both intake and exhaust valves closed, the piston returns to the top of the cylinder compressing the fuel-air mixture. This is known as the compression stroke.

C. POWER stroke

While the piston is close to Top Dead Center, the compressed air-fuel mixture is ignited, usually by a spark plug (for a gasoline or Otto cycle engine) or by the heat and pressure of compression (for a diesel cycle or compression ignition engine). The resulting massive pressure from the combustion of the compressed fuel-air mixture drives the piston back down toward bottom dead center with tremendous force. This is known as the power stroke, which is the main source of the engine's torque and power.

D. EXHAUST stroke

During the exhaust stroke, the piston once again returns to top dead center while the exhaust valve is open. This action evacuates the products of combustion from the cylinder by pushing the spent fuel-air mixture through the exhaust valve(s).

In our project we have to modified these four strokes into totally two stroke with the help of inner CAM alteration. In air engine we can design a new CAM which is operate only Inlet stroke and exhaust stroke. Actually in four stroke engine the inlet and exhaust valve opens only one time to complete the total full cycle. In that time the piston moving from top dead center to bottom dead center for two times. A stroke refers to the full travel of the piston from Top Dead Center (TDC) to Bottom Dead Center (BDC). In our air engine project, we have to open inlet and exhaust valve in each and every stroke of the engine so that it will convert the four stroke engine to two stroke engine by modifying the CAM shaft of the engine.

VII. Design and Drawings

A. Design of Ball Bearing

Bearing No. 6202

| | | |
|-----------------------------------|---|-----------------------------------|
| Outer Diameter of Bearing (D) | = | 35 mm |
| Thickness of Bearing (B) | = | 12 mm |
| Inner Diameter of the Bearing (d) | = | 15 mm |
| r_1 | = | Corner radii on shaft and housing |
| r_1 | = | 1 (From design data book) |

Maximum Speed = 14,000 rpm (From design data book)

$$\begin{aligned} \text{Mean Diameter } (d_m) &= (D + d) / 2 \\ &= (35 + 15) / 2 \\ d_m &= 25 \text{ mm} \end{aligned}$$

B. Engine Design Calculations

Design and Anlysis on Temperature Distribution for Two-Stroke Engine Component Using Finite Element Method:

1. Specification of Four Stroke Petrol Engine:

| | | |
|---------------------|---|-----------------------|
| Type | : | Four strokes |
| Cooling System | : | Air Cooled |
| Bore/Stroke | : | 50 x 50 mm |
| Piston Displacement | : | 98.2 cc |
| Compression Ratio | : | 6.6: 1 |
| Maximum Torque | : | 0.98 kg-m at 5,500RPM |

2. Calculation

Compression ratio = (Swept Volume + Clearance Volume)/ Clearance Volume

Here,
 Compression ratio = 6.6:1
 $\therefore 6.6 = (98.2 + V_c)/V_c$
 $V_c = 19.64$

Assumption:

1. The component gases and the mixture behave like ideal gases.
2. Mixture obeys the Gibbs-Dalton law

Pressure exerted on the walls of the cylinder by air is P_1

$P_1 = (M_1RT)/V$

Here,
 $M_1 = m/M = (\text{Mass of the gas or air})/(\text{Molecular Weight})$

R = Universal gas constant = 8.314 KJ/Kg mole K.

$T_1 = 303 \text{ }^\circ\text{K}$

$V_1 = V = 253.28 \times 10^{-6} \text{ m}^3$

Molecular weight of air = Density of air x V mole

Here,
 Density of air at 303°K = 1.165 kg/m³
 V mole = 22.4 m³/Kg-mole

for all gases.

\therefore Molecular weight of air = 1.165 x 22.4

$\therefore P_1 = \frac{\{[(m_1)/(1.165 \times 22.4)] \times 8.314 \times 303\}}{253.28 \times 10^{-6}}$

$P_1 = 381134.1 \text{ m}_1$

Let Pressure exerted by the fuel is P_2

$P_2 = (N_2 R T)/V$

Density of petrol = 800 Kg/m³

$\therefore P_2 = \frac{\{(M_2)/(800 \times 22.4)\} \times 8.314 \times 303}{(253.28 \times 10^{-6})}$

$P_2 = 555.02 \text{ m}_2$

Therefore Total pressure inside the cylinder

PT = $P_1 + P_2$
 = 1.01325 x 100 KN/m²

$\therefore 381134.1 \text{ m}_1 + 555.02 \text{ m}_2 = 1.01325 \times 100$ (1)

Calculation of air fuel ratio:

Carbon = 86%
 Hydrogen = 14%

We know that,

1Kg of carbon requires 8/3 Kg of oxygen for the complete combustion.

1Kg of carbon sulphur requires 1 Kg of Oxygen for its complete combustion.

(From Heat Power Engineering-Balasundrum)

Therefore,

The total oxygen requires for complete combustion of 1Kg of fuel

= [(8/3c) + (3H₂) + S] Kg

Little of oxygen may already present in the fuel, then the total oxygen required for complete combustion of Kg of fuel

= { [(8/3c) + (8H₂) + S] - O₂ } Kg

As air contains 23% by weight of Oxygen for obtain of oxygen amount of air required

= 100/23 Kg

\therefore Minimum air required for complete combustion of 1 Kg of fuel

= (100/23) { [(8/3c) + H₂ + S] - O₂ } Kg

So for petrol 1Kg of fuel requires = (100/23) { [(8/3c) x 0.86 + (8 x 0.14)] }

= 14.84 Kg of air

\therefore Air fuel ratio = m_1/m_2

= 14.84/1

= 14.84

$\therefore m_1 = 14.84 \text{ m}_2$ (2)

Substitute (2) in (1)

1.01325 x 100 = 3.81134 (14.84 m₂) + 555.02 m₂

$\therefore m_2 = 1.791 \times 10^{-5} \text{ Kg/Cycle}$

Mass of fuel flow per cycle = 1.791 x 10⁻⁵ Kg cycle

Therefore,

Mass flow rate of the fuel for 2500 RPM
 [(1.791 x 10⁻⁵)/3600] x (2500/2) x 60
 = 3.731 x 10⁻⁴ Kg/sec

VIII. Advantages

- Compressed air to store the energy instead of batteries.
- Pollution created during fuel transportation would be eliminated.
- Reducing pollution from one source, as opposed to the millions of vehicles on the road.
- There is no need to build a cooling system, fuel tank, Ignition Systems or silencers.
- The price of fueling air powered vehicles will be significantly cheaper than current fuels.

IX. Disadvantages

- The temperature difference between the incoming air and the working gas is smaller. In heating the stored air, the device gets very cold and may ice up in cool, moist climates.
- Refueling the compressed air container using a home or low-end conventional air compressor may take a long time.
- Tanks get very hot when filled rapidly. It very dangerous if caution is not maintained.
- Only limited storage capacity of the tanks. So we cannot opt for a long drive.

X. Applications

- Compressed air engines were used in trams and shunters, and eventually found a successful niche in mining locomotives
- Transport category airplanes, such as commercial airliners, use compressed air starters to start the main engines. The air is supplied by the load compressor of the aircraft's auxiliary power unit, or by ground equipment.
- There is currently some interest in developing air cars. Several engines have been proposed for these
- Impact wrenches, drills, firearms, die grinders, dental drills and other pneumatic tools use a variety of air engines or motors. These include vane type pumps, turbines and pistons.
- Most successful early forms of self-propelled torpedoes used high pressure compressed air, although this was superseded by internal or external combustion engines, steam engines, or electric motors.

XI. Conclusion

Thus we have developed an "AIR ENGINE" which helps to know how to achieve compressed air vehicle. The application of pneumatics produces smooth operation. By using more techniques, they can be modified and developed according to the applications.

References

- [1] Automobile Engg. - N.M Aggarwal S.K.Kataria & Sons.
- [2] "Advances in Automobile Engg.", S.Subramaniam Allied Publishers Ltd.
- [3] "Theory and Performance of Electrical Machines", J.B. Gupta, S.K Kataria & Sons.
- [4] "Principles of Electrical Engg & Electronics, V.K Mehta.
- [5] "Engineering and Electronics", V.K.Mehta.
- [6] [Online] Available: <http://www.visionengineer.com>
- [7] [Online] Available: <http://www.tpup.com>
- [8] [Online] Available: <http://www.wikipedia.org>