International Journal of Mechanical Dynamics & Analysis
Vol. 1: Issue 2
www.journalspub.com

System Design and Mechanism of a Compressed Air Engine

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ABSTRACT
The compressed-air vehicle, CAV, is used as compressed air as a fuel, stored in a tank, and powered by an engine. This designed vehicle consists of an air storage tank, from which the air is made to expand inside the cylinder. The air engine is derived from the steam engine. CAV has existed in various forms since two centuries.

Keywords: compressed air technology, effective renewable alternative energy, zero pollution vehicle

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INTRODUCTION
The CAV is one which uses compressed air as a fuel. This specially designed vehicle consists of an air storage tank, from which the air is made to expand inside the cylinder.

Here, the pressure energy of air is getting converted into kinetic energy. The compressed air vehicle is a ZERO POLLUTION VEHICLE because of the absence of combustion. CAV is the vehicle of the future generation when optimized.[1–5]

PRINCIPLE
The principle of the air engine is derived from the steam engine in which the pressure energy of steam is converted to kinetic energy. The air engine uses compressed air instead of steam. The compressed air has pressure which on expansion moves the piston (linear motion) which is converted to rotary motion through crank and connecting rod mechanism (Figure 1).[6,7]

Pressure Energy $\rightarrow$ ***Kinetic Energy***

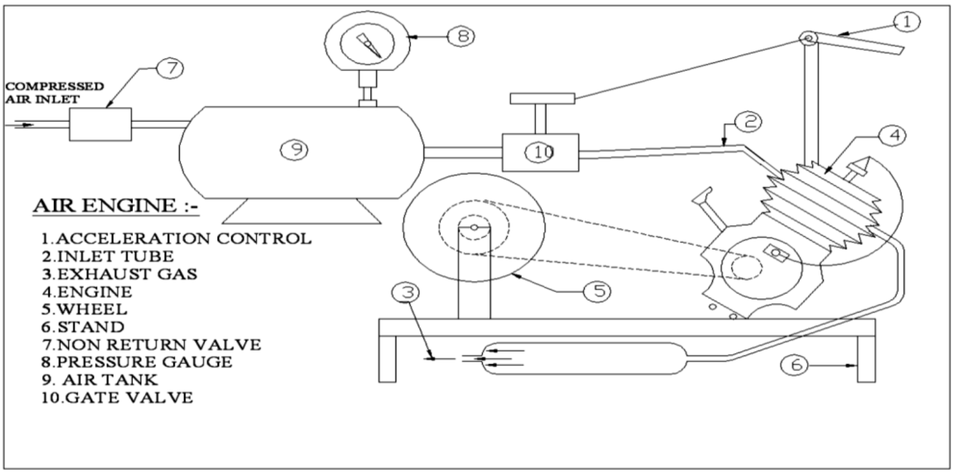


Fig. 1. *Overall CAV design specification.*

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.[8–15]

TANKS

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

The storage tank may be made of:

- Steel
- Aluminium
- Carbon fiber
- Kevlar
- 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 4500 pounds per square inch (about 30 MPa) and hold nearly 3200 cubic feet (around 90 cubic meters) 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 (Figure 2).[16–20]

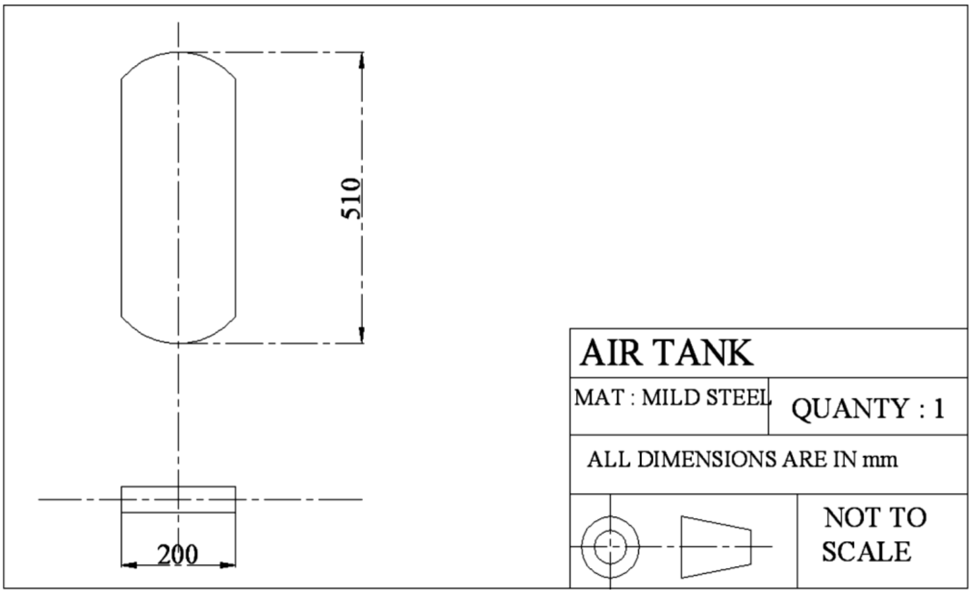


Fig. 2. *Air tank specification.*

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 liter, 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.

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.

WORKING

In the compressed air engine, the cycle of operation gets completed with two strokes of the piston or one revolution of the crank.[21]

The two strokes are:
(1) Expansion or power stroke
(2) Exhaust stroke

As mentioned earlier, air engine requires two strokes of piston or one crank revolution to complete one cycle. During the first stroke, just 11 degree after TDC, the inlet valve opens to allow air from the cylinder to expand inside the cylinder.

This causes the piston to move downward (pressure energy converted to kinetic energy). This timing avoids reversing of the engine. Then after 116 degree of crank revolution, inlet valve closes and cuts off the air supply.[22]

Then after 8 degree of crank revolution, the exhaust vent opens to allow major part of the expanded air to escape to the atmosphere. Both these timings are given in such a way that the former prevents useful air from escaping out and the latter reduces the resistance on the piston during return stroke. The crank rotates another 45 degree to take the piston to BDC, thus completing the first stroke.

During the second stroke the piston starts moving from BDC to TDC. After 14 degree of crank revolution from BDC, the exhaust valve opens which facilitates the remaining part of expanded air trapped inside the cylinder to escape to the atmosphere. After 45 degree of crank revolution from BDC, the exhaust vent closes.

At the same time the expanded air continues to escape through the exhaust valve. After this just 7 degree before TDC, the exhaust valve closes and the piston reaches TDC after 7 degree of crank revolution, thus completing the second stroke.[15,23]

EXPANSION OR POWER STROKE

During this stroke the piston moves from the TDC to BDC. At the beginning of this stroke the inlet valve is opened and allows the compressed air stored in the tank to expand inside the cylinder. This moves the piston down as pressure energy of air gets converted into kinetic energy thus producing a power stroke.

Just before reaching BDC the specially designed cam mechanism closes the inlet valve and the piston uncovers an exhaust vent through which the expanded gas escapes to the atmosphere. This reduces the load on the piston by reducing the amount of air present inside the cylinder during return stroke (Figure 3).

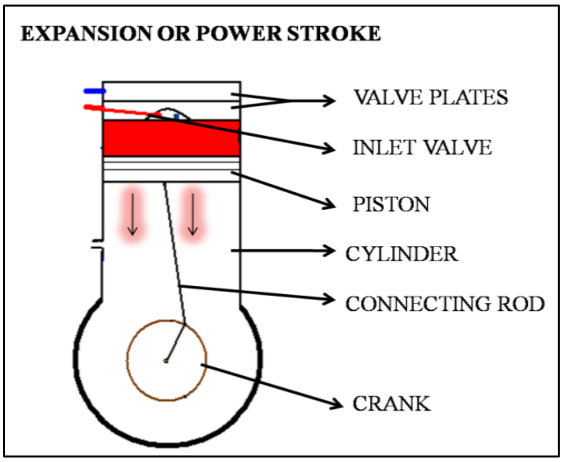


Fig. 3. Expansion stroke.

EXHAUST STROKE

During this stroke piston moves from BDC to TDC. Initially the piston covers the exhaust vent and the cam mechanism opens the exhaust valve. The remaining air trapped inside the cylinder is expelled to the atmosphere through the exhaust valve and the cycle continues (Figure 4, Table 1).

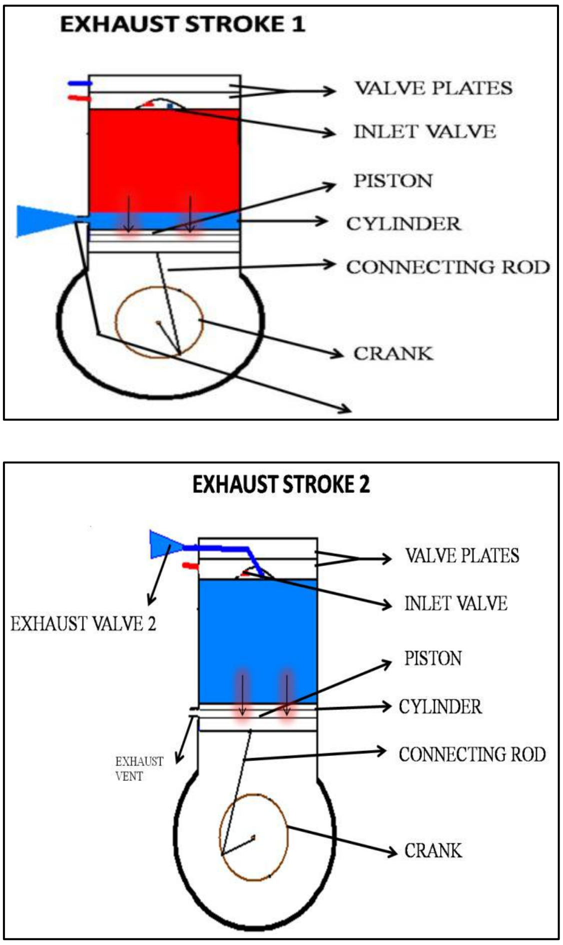


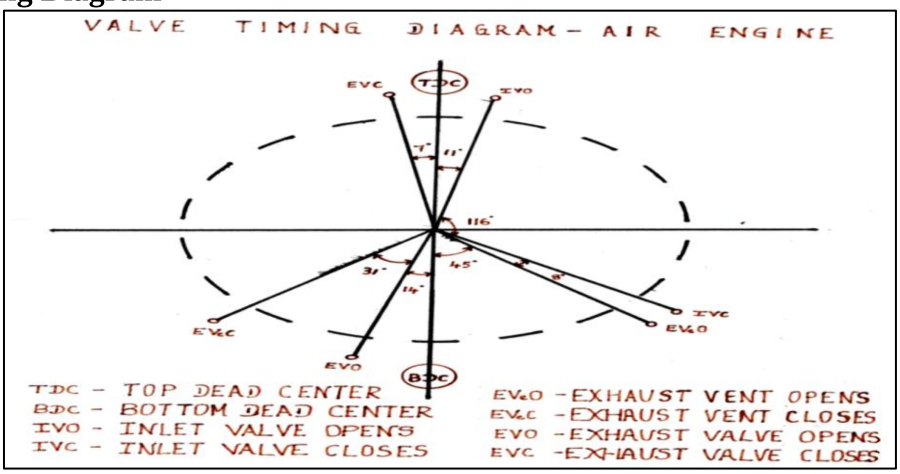
Fig. 4. Exhaust stroke.

Valve Opening and Closing in Engine

***Table 1.** Valve opening and closing in engine.*

S.no	Stroke	Event	Position w.r.t. TDC/BDC	Crank angle (in degrees)
1	Expansion or power	IVO	After TDC	11
2	Exhaust 1	IVC EVO	After TDC Before BDC	127 45
3	Exhaust 2	EVO EVC EVC	After BDC After BDC Before TDC	14 45 7

Valve Timing Diagram



NEED FOR CAV

With the exponential population hike, the usage of automobiles has also increased. The nature of the fuels (gasoline and diesel) used today is nonrenewable, expensive, highly polluting and fast depleting. This nature yields so many problems like poor economic growth, atmospheric degradation such as ozone layer depletion, acid rain etc. Motor vehicles also emit large amounts of carbon dioxide, which has potential to trap the Earth's heat and cause global warning. Moreover the emissions like Cox, Nox, Sox, CO, particulate matters cause various health hazards. In urban areas, motor vehicles are responsible for as much as 90 percent of CO in the air.

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