Proceedings of the
International Conference on Mechanical Engineeringand Renewable Energy 2015
(ICMERE2015) 26 – 29 November, 2015, Chittagong, Bangladesh

ICMERE2015-PI-125

PERFORMANCE ANALYSIS OF A COMPRESSED AIR ENGINE

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Abstract-*Now a days global warming is a great problem in this world. Any technologies that bring out the solution to this problem is considered as a bounty. In one of such new technologies, is the development of a new engine called as compressed air engine which does not require any of the known fuels like diesel, petrol CNG, LPG, hydrogen etc. This works using only compressed air. A single cylinder four stroke auto cycle engine was converted to two stroke compressed air engine running on compressed air. Since this engine runs only on high pressure compressed air, the exhaust of which is undoubtedly only air, making it a zero pollution engine. The minimum required pressure for the starting of the engine is 0.8 bar, and minimum rpm rating is 200. The rpm value increases with the increasing pressure. The mechanical efficiency of the engine is 12%.*

Keywords: Global warming, zero pollution, compressed air.

1. 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 (CAT) for its operation.

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. 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.

2. COMPRESSED AIR

Compressed air is a gas, or combination of gases that has been put under greater pressure than the air in the general atmosphere. Current application using compressed air are numerous and divers, including jackhammers, tire pump etc. according to portents, compressed air also has a great deal of potential as clean, inexpensive and infinitely renewable energy source.

2.1 Behavior of compressed air

Compressed air is clean, safe, simple and efficient. There are no dangerous exhaust fumes of or other harmful by products when compressed air is used as a utility. It is a non-combustible, non-polluting utility. When air at atmospheric pressure is mechanicallycompressed by a compressor, the transformation of air at 1 bar (atmospheric pressure) into air at higher-pressure (up to 414 bar) is determined by the laws of thermodynamics. They state that an increase in pressure equals a rise in heat and compressing air creates a proportional increase in heat. Boyle's law explains that if a volume of a gas (air) halves during compression, then the pressure is doubled. Charles' law states that the volume of a gas changes in direct proportion to the temperature [2]. These laws explain that pressure, volume and temperature are proportional; change one variable and one or two of the others will also change, according to this equation:

$(P1\ V1) / T1 = (P2\ V2)/T2$

Compressed air is normally used in pressure ranges from 1 bar to 414 bar (14 to 6004 PSI) at various flow rates from as little as 0.1 m (3.5 CFM -cubic feet per minute) and up.

2.2 How compressed air fuel a car

The laws of physics dictate that uncontained gases will fill any given space. The easiest way to see this inaction 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 cargo.

The first air cars will have air compressors built into them. After a brisk drive, you'll be able to take the car home, put it into the garage and plug in the compressor. The compressor will use air from around the car to refill the compressed air tank. Unfortunately, this is a rather

slow method of refueling and will probably take up to two hours for a complete refill. If the idea of an air car catches on, air refueling stations will become available at ordinary gas stations, where the tank can be refilled much more rapidly with air that's already been compressed. Filling your tank at the pump will probably take about three minutes.
The first air cars will almost certainly use the Compressed Air Engine (CAE) developed by the French company, Motor Development International (MDI). Air cars using this engine will have tanks that will probably hold about 3,200 cubic feet (90.6 kiloliters) of compressed air. The vehicle's accelerator operates a valve on its tank that allows air to be released into a pipe and then into the engine, where the pressure of the air's expansion will push against the pistons and turn the crankshaft. This will produce enough power for speeds of about 35 miles (56kilometers) per hour. When the air car surpasses that speed, a motor will kick in to operate the in-car air compressor so it can compress more air on the fly and provide extra power to the engine. The air is also heated as it hits the engine, increasing its volume to allow the car to move faster.

3. CONSTRUCTION

The construction of compressed air engine mainly consist of pneumatic cylinder, pneumatic solenoid valve and working, light chaser circuit, compressor, bearing &it's working, and crank shaft.

3.1 Pneumatic Cylinder

Pneumatic cylinders are mechanical devices which produce force, often in combination with movement and are powered by compressed gas.
To perform their function, pneumatic cylinders impart a force by converting the potential energy of compressed gas into kinetic energy. This is achieved by the compressed gas being able to expand, without external energy input, which itself occurs due to the pressure gradient established by the compressed gas being at a greater pressure than the atmospheric pressure. This air expansion forces a piston to move in the desired direction.
Once actuated, compressed air enters into the tube at one end of the piston and, hence, imparts force on the piston. Consequently, the piston becomes displaced by the compressed air expanding in an attempt to reach atmospheric pressure.

3.2 Pneumatic Solenoid Valve and Working

The term solenoid usually refers to a coil used to create magnetic fields when wrapped around a magnetic object or core. In engineering terms, the solenoid describes transducer mechanisms used to convert energy into motion. Solenoid valves are controlled by the action of the solenoid and typically control the flow of water or air as a switch. If the solenoid is active (current is applied), it opens the valve. If the solenoid is inactive (current does not exist), the valve stays closed. The action of the pneumatic solenoid is controlled by the use of pneumatics. The opening or closing of a valve is referred to as "changing state."
An internally driven pilot valve with four-way connections is generally found in pneumatic operations and is used to move double action cylinders. Pneumatic solenoid valves can be designed as stackable.

3.3 Light Chaser Circuit & Its Component

Light chaser circuits can be used to create lighting animation sequences and have been used in the pasttoattract attention for advertising and promotion, such as the marquee at the local movie theater. In addition, they can be used to produce pleasing effects for entertainment as well. Light chasers consist of several lighting circuits strung together, usually three or four. Every first light in the string is turned on, then off and the next light is turned on and then off, and so on. Although there are eight lights in the example below, there are only four circuits controlling these lights, which are repeated twice. The two lights that are on at any given time are connected to the same circuit. In the Rainbow Kits light chaser, the four circuits can be repeated up to10times, giving a string of 40 LEDs.

Fig.3.1: Construction of Compressed Air Engine.

3.4 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, so the main action of a pump is to pressurize and transport liquids. Compressed air Piston range operates between0.75 kW to 420 kW (1hp to 563 hp) producing working pressure at 1.5 bar to 414 bar (21 to6004psi).Compressed air Vane compressors operate between 1.1 kW to 75 kW (1.5 to 100hp), producing working pressures of 7 to 8 and 10 bar (101 to145psi).

3.5 Crank Shaft

The crankshaft translates reciprocating linear piston motion into rotation. To convert the reciprocating motion into rotation, the crankshaft has "crank throws" or "crankpins", additional bearing surfaces whose axis is

offset from that of the crank, to which the "big ends" of the connecting rods from each cylinder attach.
It typically connects to a flywheel, to reduce the pulsation characteristic of the four-stroke cycle, and sometimes a tensional or vibration damper at the opposite end, to reduce the torsion vibrations often caused along the length of the crankshaft by the cylinders farthest from the output end acting on the torsion elasticity of the metal.

4. ADVANTAGES

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. This 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.
- High torque for minimum volume.
- The mechanical design of the engine is simple and robust.
- 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 tank may be able to be refilled more often and in less time than batteries can be recharged, with re-fueling rates comparable to liquid fuels.
- Lighter vehicles would mean less abuse on roads. Resulting in longer lasting roads.
- The price of fueling air-powered vehicles will be significantly cheaper than current fuels.

5. RESULT AND DICUSSION

5.1 Results

The values noted down are used for calculating the mechanical efficiency, indicated power brake Power etc. Since this proto type was designed for low speed, the output power; applied load was also kept low. The prime aim being to test the concept of application of air and the suitability of special connecting rod assembly with its related advantages, hence the obtain result may not be the exact measure of its potential, since it wasn't very professionally designed.

5.2 Indicated Power

It can be seen that the indicated power is increasing for increase of load. As load is increased, the speed falls down, to maintain it constant injection pressure has to be increased. As the injection pressure has to be increased, the indicated mean effective pressure gets increased; hence the indicated power is increased. Indicated power is calculated by plotting the P-V diagram and calculating the area under the curve. Initial suction pressure p1 known as pressure after compression p2 of air in cylinder is also known because the compression ratio is known and the p3 is the injection pressure of air from cylinder which can be recorded from the pressure gauge, and the exhaust pressure p4 is also recorded so the p-v plot can be easily drawn as four pressures are known. Power is defined as the rate of doing work. In the analysis of cycles the network is expressed in kJ/Kg of air. This may be converted to power by multiplying the mass flow rate of air through the engine in kg/time. Since, the network obtained from the p-v diagram is the network produced in the cylinder as measured by an indicator diagram, the power based there on is termed indicated power (IP).

Indicated Power = indicated network × cycles/sec.
IP = $(P_{im}\ LANK)/60000\ kW$
Where, Pimep = indicated mean effective pressure (0.8, 1.0, 1.6….2.0) (bar),
L = Length of stroke (meter),
A = area of piston (m^2),
N = speed in revolution per minute,
n = no. of power stroke per minute (N for a two stroke engine),
K = no. of cylinder.
Observations of indicated power are as follows:-
The value of K = 1, L = 0.064 m, A = 0.001257 m^2

Observation I, (IP) = $\frac{P_{im}LANK}{60000}$

$$= \frac{1 \times 10^5 \times 0.064 \times 0.001257 \times 295 \times 1}{60000}$$
$$= 0.0395536\ kW$$

Observation II, (IP) = $\frac{P_{im}LANK}{60000}$

$$= \frac{1 \times 10^5 \times 0.064 \times 0.001257 \times 320 \times 1}{60000}$$
$$= 0.0429056\ kW$$

Observation III, (IP) $= \frac{P_{im}LANK}{60000}$

$$= \frac{1 \times 10^5 \times 0.064 \times 0.001257 \times 370 \times 1}{60000}$$
$$= 0.0496096\ kW$$

5.3 Brake Power

The brake power was increasing upon the application of the load. Though the applied load is smaller, however, the developed power was in proportion to the applied load. As load was applied the speed was reduced, to maintain it constant, the inlet air pressure has to be increased. As shown injection pressure is increased. In the present case the speed was maintained constant as 350 rpm. As the output speed was less the brake power was significantly lower. In general, only the brake power, BP, has been used here to indicate the power actually delivered by the engine. The product of the moment arm R & the measured force, F is termed the torque of the engine& is usually expressed in Nm. Torque, T is the uniform or fluctuating turning moment, or twist, exerted by tangential force acting at a distance from the axis of rotation. For an engine operating at a given speed and delivering a given power, the torque must be fixed amount, or the product of F and R must be the constant (T=FR). In case, R is decreased, the F will be increased proportionately and vice-versa.

Brake power (BP) $= \frac{2\pi NT}{60000} kW$

SL No.	RPM (Average)	Load (Newton)	Length (meter)	Torque $= load \times length$
1.	325	2.5	0.054	0.135
2.	325	2.7	0.054	0.145
3.	325	3	0.054	0.162

Table 4.1: Observation of torque

The observational view of brake power is as follows –

Observation I, (BP)$= \frac{2\pi NT}{60000} kW$

$$= \frac{2 \times 3.14 \times 325 \times .135}{60000}$$
$$= 0.004594\ kW$$

Observation II, (BP)$= \frac{2\pi NT}{60000} kW$

$$= \frac{2 \times 3.14 \times 325 \times .145}{60000}$$
$$= 0.004934\ kW$$

Observation III, (BP)$= \frac{2\pi NT}{60000} kW$

$$= \frac{2 \times 3.14 \times 325 \times .162}{60000} = 0.0055513\ kW$$

5.4 Mechanical Efficiency

The mechanical efficiency is increasing with the increase of output power. At lower output it was very low. However the overall mechanical efficiency is low compared to the conventional engine, the reasons being the addition of three extra joints and the rotating pairs which has increased the frictional loss. The slightly oversized links also has contributed significantly in increasing the frictional force and high initial torque required to set the link in the motion. This can however be improved by optimizing the link sizes, and reducing the frictional loss in the rotating pairs.Mechanical Efficeincy (η_m)

$$= \frac{\text{Breaking Power}}{\text{Indicated Power}} = \frac{0.004594}{0.0395536} = 12\ \%$$

5.5 Discussion

This is a revolutionary engine design which is ecofriendly, pollution free, but also very economical. This redresses both the problems of fuel crises and pollution. However excessive research is needed to completely prove the technology for both its commercial and technical viability. It can be seen that the indicated power is increasing for increase of load. As load is increased, the speed falls down, to maintain it constant injection pressure has to be increased. As the injection pressure has to be increased, the indicated mean effective pressure gets increased; hence the indicated power is increased upon the application of the load. Though the applied load was small, however, the developed power was in proportion to the applied load. As load was applied the speed was reduced, to maintain it constant, the inlet air pressure has to be increased. As shown injection pressure is increased. In the present case the speed was maintained constant as 350 rpm. As the output speed was less the brake power was significantly lower. The mechanical efficiency is increasing with the increase of output power. At lower output it was very low.

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8. NOMENCLATURE

Symbol	Meaning	Unit
IP	Indicated power	KW
BP	Brake power	KW
L	Length of Stroke	Meter
A	Area of Piston	$Meter^2$
N	Speed	rpm
T	Torque	N-m