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Design, Development and Performance Evaluation of a Compressed Air Engine

I Balaguru[1], A Babu[2], T Arunkumar[3], A David[4]

[1,2,3,4]Department of Mechanical Engineering, Karpagam Institute of Technology, Coimbatore, Tamilnadu, India

Abstract- *In the past few decades, energy conservation and carbon reduction have become very crucial issues worldwide. Researchers have been searching for solutions to reduce the extensive use of conventional internal combustion (IC) engines and to reduce their carbon dioxide emissions. The green energy technologies such as Electric vehicles, Hydrogen engines and Natural gas engines have been developed to replace the engine in motor vehicles. However, there are several disadvantages are barrier to implement above technologies. Nowadays the most of the compressed air engine technology becomes more popular due to its simplicity. The engine can be run by the utilization of compressed air Technology which works by cyclic Expansion and Compression with in a Confined medium. Only a few researches and industrial projects have focused to develop a compressed air engine. In this paper, a compressed air engine has been designed and developed. The compressed air engine is developed from a 50c.c internal combustion (I.C.) engine obtained from a motorcycle manufacturer. The position of inlet and outlet valves have been modified in conventional two stoke engine, using roller type solenoid valves for controlling air inlet. In order to examine the power performance and pressure variations of the compressed air engine an experimental test bench is designed and developed. The power performance and emission exhaust of the conventional and compressed air engine is also compared.*

Keywords: *Engine, Compressed Air, Internal Combustion, Performance*

I. INTRODUCTION

An Internal combustion (IC) engine is a heat engine where the combustion of fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine the expansion of the high-temperature and high-pressure gases produced by combustion apply direct force to some component of the engine. The force is applied typically to pistons, turbine blades, or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy. The first commercially successful internal combustion engine was created by Lenoir around 1859and the first modern internal combustion engine was created in 1864 by Siegfried Marcus. The term internal combustion engine usually an engine in which combustion is intermittent, such as the more familiar four-stroke and stroke piston engines, along with variants, such as the six-stroke piston engine.

The entire I.C. engine when they operate pollutes the environment through hot combustion gases. The automotive vehicle and industrial power unit using internal combustion engine are major contributors to this problem. The major pollutants are Carbon monoxide, Nitric Oxide, Hydrocarbons Smoke or particulate, and Sulphur Oxide. The Pollution in engine can be controlled by reducing the Emission in engine exhaust by the several ways. Such as additive with Fuel, Addition of Effluents with fuel, altering the Fuel Composition and Alternate Fuel usage

Betroli et al. (1993) suggest that the particulate emission reduction could be attained using the ash less additive technology. The

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different fuel characteristics are studied. They found that it is necessary to use conditioning period prior toemission tests [1]. Kouremenous et al. (1999) examined the effect of the fuel composition and physical properties on the mechanism of combustion and pollutant formation. A number of fuels having different density, viscosity, chemical composition,(especially aromatics(type), are used in their investigation and found that the fuel properties namely density and viscosity are more important than fuel composition (aromatics) in respect of engine6performance and emissions. The total aromatic content, however, has more influence on engine performance and emissions rather than the individual aromatics [2].

Hajdukovic et al. (2000) reported that the toxicity of diesel fuel is generally attributed to soluble aromatic compounds. Alkyl derivatives of benzene and polycyclic aromatic hydrocarbons are considered as most harmful. New oxygen and nitrogen derivatives of hydrocarbons are formed as a result of oxidative and paralytic processes during combustion [3]. The diesel fuel being heavier and having higher carbon content has some problems when used in an engine. Due to its high freezing point, it is known to cause blockage of filters and nozzles especially under cold conditions. The routine use of fuel additive in diesel began in 1960's in Europe as cold flow improvers. The additives added in parts per million (ppm) levels achieve a specific objective of either improving the physical or chemical characteristics of the fuel or improving the combustion characteristics. There are many other functions of additives. Based on the function and additive concept, they are reported to be classified

Owen Kieth et al, (1990) as antioxidants and stabilizers, metal deactivators, cetane improvers, combustion improvers, detergents, corrosion inhibitors, anti static additives, de-hazers and de-mulsifiers, anti-icers, biocides, anti-foamants, odor masks and odorants, dyers and markers and drag reducers [4]. Kidoguchi et al. (2000) in their investigations reported that in fuels with higher aromatics content, the pyrolysis of fuel will not be satisfactory and therefore there are local high temperature regions on account of higher adiabatic flame temperature capability of ring structure hydrocarbons[5]. The aromatic compounds are very compact with very less surface to volume ratio compared to long chain normal polymers. They have higher C/H ratio and also cm ratio per unit volume. They are also more reactive because of lower C-C bond strength compared to C-H bonds. Hence, in the absence of air, they are prone to higher cracking, pyrolysis and agglomeration with other aromatic molecules nearby during the initial stages of combustion. Their adiabatic flame temperatures are also very high and as a result, soot formation increases (Hirao et al., 1988). Due to higher bond strength of O-H bonds compared to C-H and C-C bonds, O-H bonds break up in presence of high local temperatures and bring the local temperatures down. This decreases the possibility of formation of NOx. The O-H bonds are reformed as the temperatures decrease and the absorbed energy is given back [6].

Jensen et al (1983) observed that the concentrations of alkyl homologues of PA Hand oxy-PAH in the particulates were found to decrease with increasing cylinder exhaust temperatures. The degree of alkylation for the most abundant homologue of these compounds increased by one to two carbons as the cylinder exhaust temperature decreased. The inverse relationship between engine temperature and production of extractable organics suggests one possible emission control strategy. The post combustion reactor might achieve reduction of PM associated with organics. To evaluate the feasibility of such an engine modification, both particulate and vapour emissions need to be collected simultaneously. This will allow proper correlation of particulate vapour with the engine conditions.

Jhon et al. (2000) processing Air to power vehicle gives comparatively less heating of engine and provides maximum utilization of work [7]. This Engine speed can be altered easily by simple control valve Stage de Caro (2006), Tank storage capacity , Compressor Type used for filling air , Weight of engine are considered for maximum utilization of work. Air engine reduces fuel cost and Mechanical Components allied for firing so ultimately economically air engine can compete on market [8].

In today's scenario, the internal combustion engines are mostly run using the fossil fuels. The fossil fuels are extinct to the world by 2030.Also the internal combustion engines exhaust are harmful and they emit emissions to the surroundings. So, the development of the alternative fuel is most important. This paper discusses design and development of the compressed air engine by modifying the two stroke petrol engine. The performance of the newly developed compressed air engine is compared with performance of the two stroke engine.

II. Construction and Working of Compressed Air Engine

The main parts of the compressed air engine and working of the compressed air engine are discussed in this chapter clearly. The schematic diagram of the compressed air engine is shown in the fig.1.

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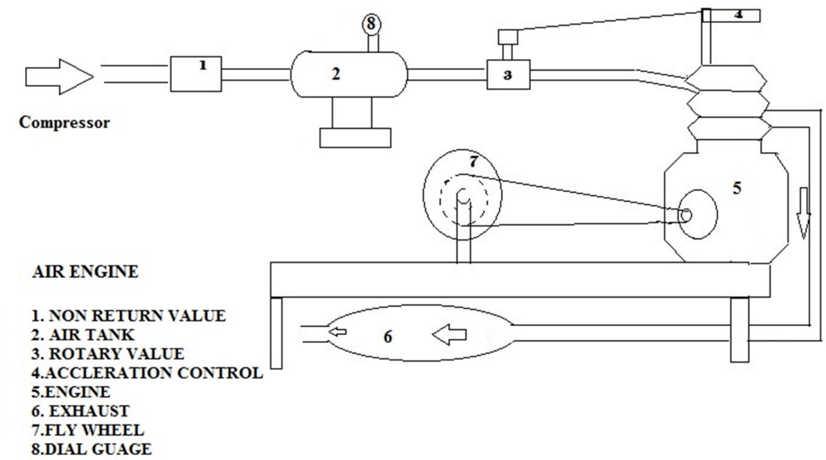


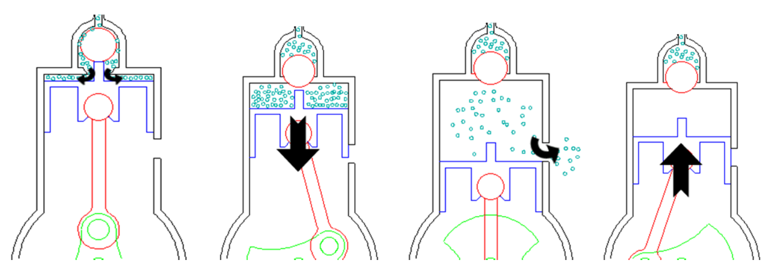
Fig.1 Schematic diagram of compressed air engine

A pneumatic motor or compressed air engine is a type of motor which does mechanical by expanding compressed air. Pneumatic motors generally convert the compressed air energy to mechanical work through either linear or rotary motion. Linear motion can come from either a diaphragm or piston actuator, while rotary motion is supplied by either a vane type air motor or piston air motor.

Pneumatic motors have existed in many forms over the past two centuries, ranging in size from hand-held turbines to engines of 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. Pneumatic motors have found widespread success in the hand-held tool industry, and continual attempts are being made to expand their use to the transportation industry. However, pneumatic motors must overcome inefficiencies before being seen as a viable option in the transportation industry.

Table I: Specification of a compressed air engine

No of cylinder	1
Displacement (mm)	50
Bore Diameter(mm)	40
stroke length(mm)	39
Maximum Power(kW)	2.1
Maximum Torque(Nm)	4
Start	Kick Start
Speed (RPM)	1200



(a) Inlet Process (b) Expansion (c) Exhaust (d) Compression

Figure 2 Working Principle Air Engine

The conventional IC engine was originally installed in a two wheeler obtained from TVS 50, motorcycle manufacturer in India. The thermodynamic cycle of the single-cylinder piston-type compressed air engine in a 2-stroke operation consists of four processes namely Intake, Expansion or Power, Discharge and Compression.

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A. Intake Process

At the beginning of the intake process, the intake valve opens immediately, and the exhaust valve stays closed while the piston moves from the top dead center (TDC) toward the bottom dead center (BDC) is shown in the figure 2(a) .During this process, the incoming compressed air pushes the piston downward, producing the power stroke.

B. Expansion Process

The intake valve closes before the piston reaches the BDC to reduce the air consumption, and thus changing the process from a constant pressure expansion to an isentropic expansion. The downward movement of piston produces work while the compressed air feeds into the cylinder during the intake process, and even after the intake valve closes during the isentropic expansion process is shown in the 2(b).

C. Exhaust Process

At the start of the exhaust process, the exhaust valve opens immediately while the intake valve remains closed is shown in the figure 2(c). The piston moves from the BDC toward the TDC to discharge the compressed air from inside the cylinder. The cylinder pressure during the exhaust process is always greater than the ambient pressure to facilitate discharging.

D. Compression Process

If the exhaust valve closes before the piston reaches the TDC, it adds an isentropic compression process to the cycle. The isentropic compression requires work to compress the air in the cylinder, and therefore, reduces the total work output of the whole engine cycle.

III. Results and Discussions

The Torque and Power output from the compressed air engine were evaluated (averaged after 200 cycles) at the test bench at various supplied air pressures. The maximum supplied air pressure during the experiments was limited to 7 bar, which is the highest pressure that small/medium size air compressors can provide. The highest torque 4N·m was at 7 bar and 465 rpm, and the highest power output of 2.1 kW was obtained at 7 bar and 1200 rpm. The flow rates of the compressed air engine (supplying pressure: 7 bar) as the rotation speed changes from 500 rpm to 1200 rpm. The highest torque and power output were obtained at the highest supplied air pressure, indicating that the highest air pressure provides the highest force applied on the piston which is shown in the figure 3.

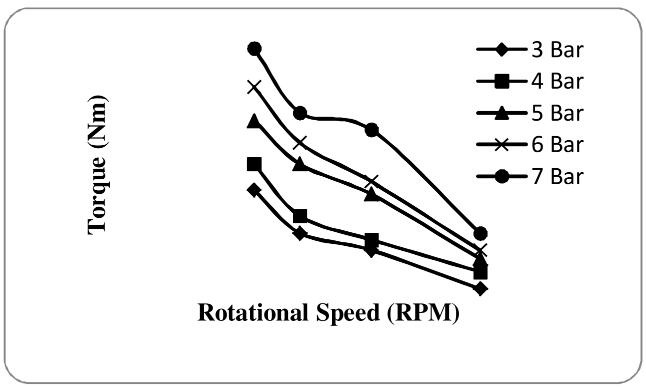

Fig. 3 Speed Vs Torque

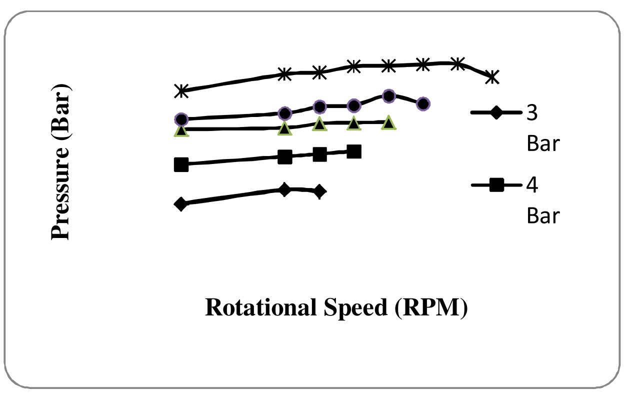

Fig. 4 Speed Vs Pressure

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To further study the effects of the limited lift during the intake and exhaust processes, this study uses simplified thermodynamic models to calculate the pressure variation inside the cylinder by using commercial Analytical Calculation. The calculations in this study are based on the ideal gas law, with the thermodynamic models and the assumption of no friction. The sinusoidal equation was used for estimating the valve movement. The area for the flow passage is calculated by the circumference of the valve and distance between the port and valve, and it changes with the valve movement. Figure 4 show the pressure variation at varies from 3bar to 7 bar and 1200 rpm, and provides a comparison of these results with the acquired experimental data. An infinite lift represents no area constraint from the valve movement, and the area for the flow passage was fixed as the diameter of the port size. Without the valve lift constraint, the pressure increases immediately after the intake valve opens. The pressure decreases slightly while the piston moves to the BDC because of the limited air flowing into the cylinder which does not suffice to fill the increased space during expansion. If the valve lift decreases to 2 mm, the intake air flow decreases further, and the pressure gradually increases. Because of the lower flow rate, the pressure decrease during volume expansion is not obvious. The pressure decrease during the exhaust process with a 1 mm valve lift is not as much as that at a larger valve lift, and a higher residual pressure inside the cylinder appears in both the experimental data.

Table II: Performance analysis

	Conventional Petrol Engine	**Compressed Air Engine**
No of Strokes	2	2
Power (kW)	2.1	0.82
Brake Horse power	3Bhp	.09Bhp
Speed (RPM)	1200	650
Torque	4Nm	2.94Nm
Mechanical Efficiency	82%	71%
Emission Rate CO	3.40 ppm	0.73 ppm

IV. Conclusions

Compressed air engine has been designed and developed by altering inlet value in Two stoke Engine. The Performance of the Engine has been Experimentally Compared with Conventional petrol Engine with Compressed air engine. The following conclusions are made

- Mechanical Efficiency of Modified Compressed Air Engine is 71 %.
- Emission of air engine is minimized to 78%.
- In future the performance on Compressed air engine can be increased by increasing cylinder diameter and stoke length.

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