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A Comparative Experimental Study of Compressed Air Engine in Existing Single Cylinder 2 Stroke and 4 Stroke Engines

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Abstract: ***Keeping in view the internal-combustion engines pollute the environment seriously ,the climate change, the dependence on petroleum reserves as the primary energy source, and volatile fuel prices, it is necessary to discover possible opportunities in unconventional alternative-fuel technologies. One of the choices available is the Compressed Air Vehicle (CAV), or air car, which are offer environmental and economic benefits like zero emissions. In this paper, a physical model of compressed air engines (CAEs) is established from existing 4 stroke and 2 stroke petrol engine. To obtain performance on the CAEs, a setup is prepared with dynamometer. The output torque, break power and fuel consumption are obtained through experimental study. The results show that CAE has a good economic performance at constant pressure 6 kg/cm^2 provide max 0.886 kW power output with varying load 0.5 kg to 2.5 kg for modified air engine from existing 4 stroke engine and 2 stroke engine. This research can be referred to in the optimization of air-powered engine.***

Keywords: compressed air engine, piston type, experiment, different loading condition, brake power

1. Introduction

The burning of fossil fuels has been recognized as the main cause of serious environmental issues, including the greenhouse effect, ozone layer depletion and acid rain. Renewable fuels, such as wind, solar, compressed air, etc., are used as obvious solutions [2]. With respect to environmental protection, Shafiee and Topal believe that oil and gas reserves may be diminished in 2042; this enhances the competition in the field of renewable energy vehicles [3]. Because of its low cost, safe maintenance, easy access, recyclability, higher energy storage density and long lifespan, compressed air energy storage will be an advanced and rapidly developing field in the future. The flow characteristics of compressed air in equipment have been studied [4-6]. Most applications of compressed air engines focus on auxiliary systems or systems that assist IC engines [7-9]. Only a few studies or industrial projects have focused on the application of a compressed air engine as the main power system [10]. Compressed air is a potential clean and environmental-friendly energy carrier. When the pressure and temperature of the compressed air are 30MPa and 300 K, respectively, the energy density is close to that of the lithium battery[11]. Furthermore, the air tank can be completely refilled in a much less time than batteries,[12] and the price of compressed air engine (CAE) is relatively cheaper [13]. The feasibility of compressed air as a vehicular energy source has been researched. CY Huang et al.[14] created CAE by modified conventional IC engines. Motor Development International (MDI) [10] have developed airpod for transportation vehicle. A small air turbine with vaned-type rotor has been developed by BR Singh and O Singh.[15] A single screw expander working with compressed air was developed by W He et al.[16]This study focuses on the experimental investigation of a compressed air engine to be installed in vehicles as a main power system. These results can be used to evaluate practical applications of compressed air engines and possible solutions in improving the efficiency and extending the duration time. Compressed air engines have been studied and used for decades in the form of power motors, known as pneumatic power tools or air motors. These power tools and air motors can operate in hazardous environment with flammable or acid gases where conventional electrical power tools are inapplicable. These pneumatic power tools or motors can be categorized as piston- and vane-types, and they can operate at high rotation speed with specified functions such as dental equipment.

However, pneumatic power tools operating at a high rotation speed require a high air flow rate, which limits the duration of operation if no air compressor is connected. Therefore, a pneumatic power tool or air motor with moderate air consumption is critical for sustainable applications [17].To use pneumatic air motors as a power system to drive motor vehicles, the power output and air consumption are critical factors when evaluating the feasibility of such an engine system. Vane-type air motors typically require a higher air flow rate than piston-type air motors because they require continuous compressed air pushing the vane [18]. To simplify the analysis, this comparative Experimental Study of Compressed Air Engine in Single Cylinder 2 Stroke and 4 stroke engines investigate its power output.

2. Experimental Method

4-stroke internal combustion engine in not suitable for CAV because CAV completes its cycle in 2-stroke so modification is required to 4-S to 2-S engine, for present study, focused on change in valve timing mechanism .Cam profiling represents basic idea of converting the four strokes engine to the two strokes engine, here Figure (1), a and b shows Pictorial view of the Conventional cam with Valve timing diagram of conventional engine and Figure (2), a to d de-scribes the dimension and present view of cam with valve timing diagram. For replacing the original cylinder head, a new set two flank cams has been designed for operating the inlet and exhaust valves of the modified engine. Both the exhaust and inlet cams are symmetric about the center line of the cam shaft. The cams are made of mild steels. The cam shaft originally had two cams with one lobe each which were mutually perpendicular to each other. The crank rotates due to the movement of the piston; the camshaft is attached with the crankshaft by a timing chain or a timing belt. And as the crank rotates the camshaft also rotates and hence the timing of the valves is managed. In the traditional camshaft the inlet and exhaust valve both functions. Table (1) and Table (2) lists the specification of the 4-stroke IC engine and 2-stroke IC engine, which was modified in the current study as a single cylinder piston type compressed air engines.

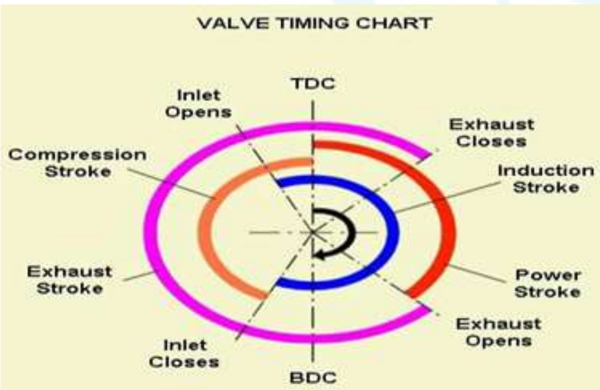
Table 1: Engine Specifications for 4-stroke engine

Parameter	Honda Sleek
Engine displacement	97.2 cc
Engine type	air cooled ,4 stroke
Number of cylinder	1
Valves per cylinder	2
Max power	7.0 ps @8000 rpm
Max torque	7.5 nm
Bore*Stroke	50 mm*49.5 mm
Fuel type	petrol
Starter	kick
Number of speed gear	4

Table 2: Engine Specifications for 2-stroke engine

Parameter	Suzuki Max 100
Engine displacement	98.2 cc
Engine type	air cooled ,2 stroke
Number of cylinder	1
Valves per cylinder	0
Max power	7.9 ps @5500rpm
Max torque	9.8 nm @5000 rpm
Bore*Stroke	50mm*50mm
Fuel type	Petrol
Starter	Kick
Number of speed gear	4

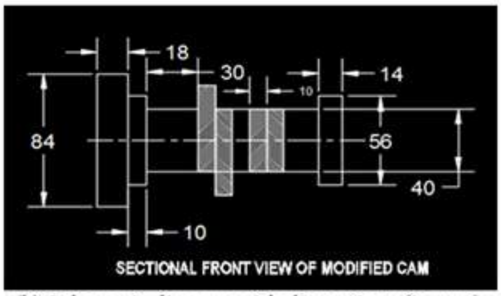
(a) Pictorial view



(b) Valve timing diagram of conventional engine

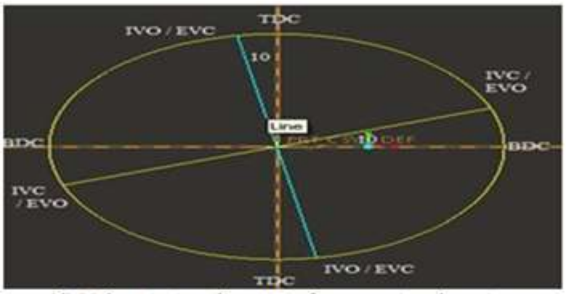
Figure 1: Conventional cam

(a) Model



(b) Schematic diagram with dimensions (in mm)

(c) Pictorial view



(d) Valve timing diagram of conventional engine

Figure 2: Modified cam

Before the experiments, the 97.2 cc Internal Combustion engine was modified and connected to a compressed air tank. The cam profile was modified to be conjugate to change the engine from 4-stroke to 2-stroke operation. After the engine was installed, the intake and exhaust valves were examined for possible leakage under high-air-pressure operation. The leakage of the intake valve was thus close to the flow rate in the experiments, and it seriously affected the performance of the compressed air engine. The exhaust valve leakage was examined when the engine was locked in the intake process, and no leakage was observed. The experimental set up for 4 stroke single cylinder air engine is shown in Figure (3).

Air cylinder is used for storing the compressed air. This air is passes through air pipe to inlet valve by adjusting flow control valve. The pressure of air (storage) in cylinder is 140 kg/cm^2.one pressure regulator valve is used to regulate pressure which supply constant pressure from the cylinder to the engine. Hear pressure drop is takes place in intake manifold of conventional engine so one nozzle is fitted which gives efficient work. One end of tube is connected with regulator out let and other with nozzle inlet.

For 2 stroke IC engine experimentation work, Suzuki max 98.2 cc engine is used as air engine, a normal two stroke engine contained several ports and it also having the spark plug which will not required for air engine. So, several modifications have done for air engine i.e. closing the transfer port and inlet port and also providing an inlet at the place of the spark plug with solenoid valve and push button Switch System. The experimental set up for 2 stroke single cylinder air engine is shown in Figure (4) and Figure (5) shows the Push Button Switch System.

For load testing of air engine, it is connected with the rope break dynamometer with brake drum, spring balance, belt and holding frame. Brake horsepower is the measure of an engine's horsepower without the loss in power caused by the gearbox, alternator, differential, water pump, and other auxiliary components such as power steering pump, muffled exhaust system, etc. Brake refers to a device which was used to load an engine and hold it at a desired RPM. During testing, the output torque and rotational speed were measured to determine the brake horsepower. Horsepower was originally measured and calculated by use of a brake drum connected to the engine's output shaft. Brake power is the power produced by the engine as measured by the brake drum. For specific air consumption, mass flow rate is calculated by use of weighing balance for particular time period.

The observations were noted at constant pressure 6 kg/cm^2 with varying load condition.

Figure 3: Experimental set up for 4 stroke single cylinder air engine

Figure 4: Experimental set up for 2 stroke single cylinder air engine

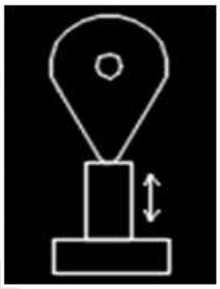


Figure 5: Push Button Switch System

3. Results and Discussion

Figure (6) shows the relationship between load and speed for 2 stroke and 4 stroke air engine. from this figure, it can be seen that for a given load speed achieved with 4 stroke air engine is more than that with 2 stroke air engine for a load of 0.5 kg to 1 kg but for a load of 1.5 kg to 2.5kg amount of speed increase from 2 stroke to 4 stroke air engine is not remarkable. e.g. A load of 0.5 kg speed increase by 73% and for 2.5kg load it is just 9%.from this figure it can be also seen that with increasing load speed decreases for both 2 stroke and 4 stroke air engine at particular inlet pressure but amount of decreasing speed is not significant for 4 stroke air engine compared to 2 stroke air engine. The results in analysis after correlating speed with load is expressed by the polynomial equation .from the coefficient determination R^2 it was noted that speed correlatively better with load.

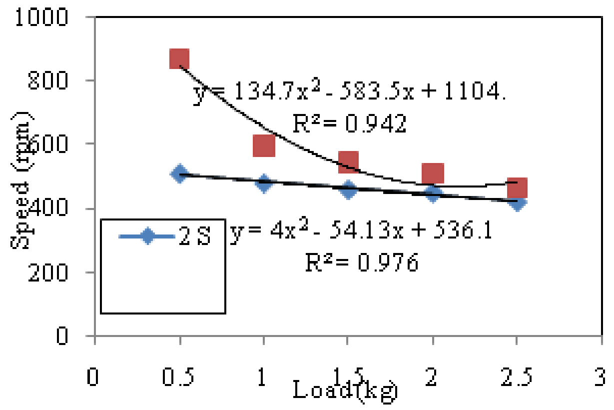


Figure 6: Plot of Speed vs. Load

Figure (7) shows the relationship between load and brake power for 2 stroke and 4 stroke air engine. from this figure ,it can be seen that with increasing load brake power increases for both 2 stroke and 4 stroke air engine at particular inlet pressure. Reason for that brake power is a function of torque and torque is directly proportional to load.

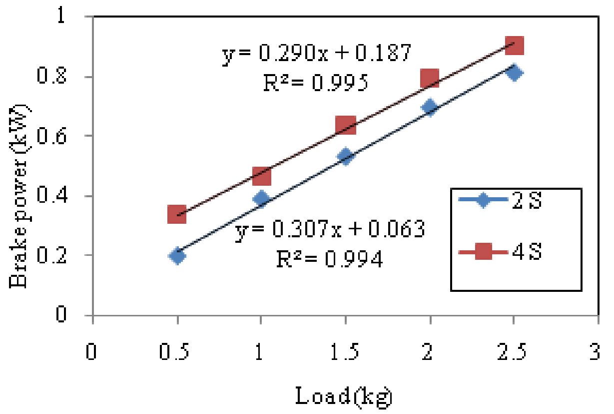


Figure 7: Plot of Brake power vs. Load

Figure (8) shows the relationship between load and mass flow rate for 2 stroke and 4 stroke air engine. From this figure, it can be seen that with increasing load mass flow rate increases for both 2 stroke and 4 stroke air engine at particular inlet pressure. at a particular inlet pressure the speed, brake power and mass flow rate of the 4 stroke air engine are more favorable than those of a single cylinder 2 stroke air engine.

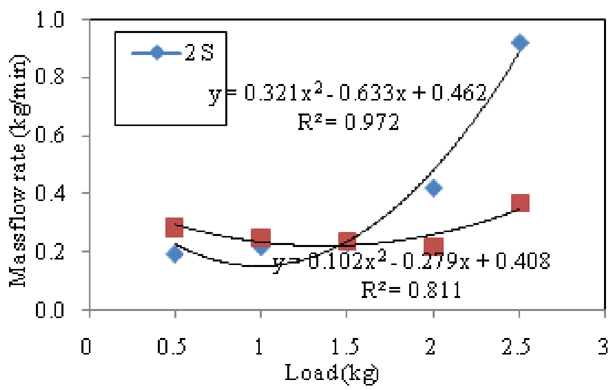


Figure 8: Plot of Mass Flow rate vs. Load

4. Conclusion

This study presents that compare the performance of the compressed air engine, which was modified from a commercially available 4 stroke and 2 stroke IC engines, at constant pressure 6 kg/cm^2 with varying load 0.5 kg to 2.5 kg performance was investigated. Engine output power is obtained max 0.886 kW for modified air engines from existing 4 stroke engine and 2 stroke engine. The engine speed for a load of 0.5 kg to 1 kg, speed achieved with 4 stroke air engine is more than that with 2 stroke air engine but for a load of 1.5 kg to 2.5 kg amount of speed increase from 2 stroke to 4 stroke air engine is not remarkable.

The brake power increases with increasing load for both 2 stroke and 4 stroke air engine at particular inlet pressure because the brake power is a function of torque and torque is directly proportional to load. The mass flow rate increases with increasing load for both 2 stroke and 4 stroke air engine at particular inlet pressure and at a particular inlet pressure the speed, brake power and mass flow rate of the 4 stroke air engine are more favorable than those of a single cylinder 2 stroke air engine.
On the whole, the technology is just about modifying the engine of any regular IC engine vehicle in to an air powered engine. Compressed air technology allows engines that are both non polluting and economical and its wide spread use will help mankind in controlling the serious problem of global warming.

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