Design and Development of Air Powered Reciprocating Two Stroke Engine

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Abstract- **Due to increased use of fossil fuels in present times, not only we are on the verge of depletion the fuels but also by utilizing them on a vast scale, we are polluting the environment leading to increased global warming. There are millions of cars on roads already so it would be illogical to withdraw all the automobiles, so it is better to modify internal combustion engine to an efficient air engine with minimal cost. For Simplification, in this paper we are considering 2-stroke internal combustion Engine. There are two primary concerns which needed to be addressed for the changeover. One is to determine the position of air supply from a place where maximum work could be extracted. The other one is the design of timing circuit to precisely decide the point of entry of air and the duration for air supply.**

Keywords – ***Air powered engine, 2 stroke reciprocating engine, IR Sensors,Hybrid engine, Arduino.***

I. INTRODUCTION

The principle of compressed-air propulsion is to pressurize the storage tank and then connect it to something very like a reciprocating steam engine of the vehicle. Instead of mixing fuel with air and burning it in the engine to drive pistons with hot expanding gases, compressed air vehicles use the expansion of compressed air to drive their pistons. The concept of air-powered engine is not at all recent. There have been attempts for designing a new engine as well as modifying an existing engine[2]. But, the air-powered engine in general has some inherent merits and demerits.

The prominent merits are:

1. The fuel i.e. air, is non-combustible and non-polluting. In addition to that, the price of the fuel is lower than conventional fuels.
2. There are just a few auxiliary systems, so the overall cost is reduced and maintenance becomes easy and cheap.
3. Air is compressed at the refuelling station, hence no transportation cost of the fuel. Further, the refuelling rates are much higher as compared to other non-conventional options.
4. The environmental impact of these engines is almost negligible. The fuel and the storage medium have no effect on the environment at all.

There are always two sides of a coin. The other side i.e. the demerits are:

1. The energy density of the fuel is considerably low, hence making it unsuitable for high speed applications.
2. As the fuel is utilized, pressure drop in the tank occurs. This affects the range as well as the maximum velocity of the automobile.
3. As there is expansion of air in the engine, in lower temperatures, the engine may ice-up.
4. Pressure in the tank is considerably high. Hence in case of a mishap, there is a serious threat of the bursting of the air-tank.

Keeping in mind, the above points, the air engine is appropriate for:

1. Automobiles in mining industry where even a small spark can lead to a catastrophe.
2. Companies that use compressed air in their processing like the textile industry. After processing, the air exhausted is still at high pressures. Here the air engine can be coupled with a generator and the power produces can be used to run other small systems. This will lead to considerable amount of savings.
3. A pneumatic hybrid. The major demerit is the energy density. If speed is required, a coupling with other system is necessary for high speeds. This will give the advantage of economy and environment friendliness as well as the need for high speed[3][5].

II. DEVELOPMENT OF AIR-ENGINE

Converting an internal combustion engine to air-engine requires certain modification and additional parts as well. The components of the air-engine setup are:

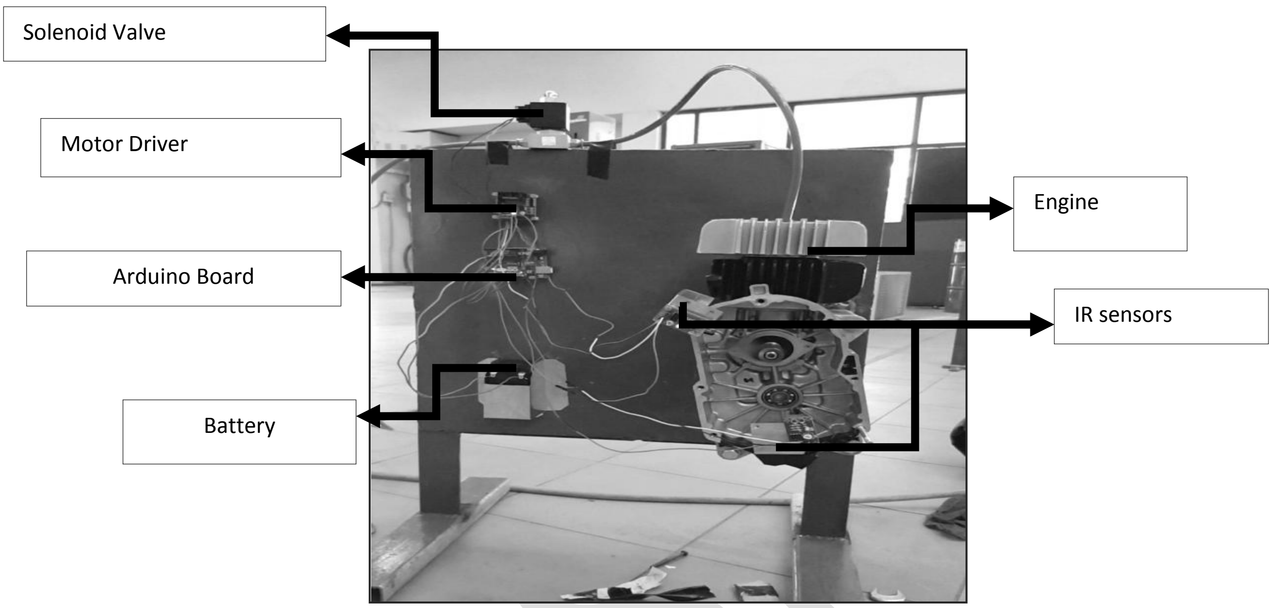
1.Two-stroke reciprocating engine, 2.Flywheel, 3.Solenoid valve, 4.IR sensors, 5.Arduino board, 6.Motor *driver, 7.Battery, 8.Pressure gauge, 9.Piping, 10.Electrical wires, 11.Connectors*

The objective was to make an efficient reciprocating air engine. The lightest available engine which met the requirement was a 2-S 70 cc TVS Luna engine. This engine could easily be modified because of its simple nature many of which, one of many is the absence of cam and cam shafts obviating the requirement for major modification. There were mainly two modifications required in the engine.

1. Induction port for from a place where maximum work could be extracted

2. Designing a timing circuit for the supply of air

Fig.1 Experimental setup



The modified engine is shown in Figure 1. There is an induction port for the supply of fuel in a 2-S engine. The supply of air is made through a different port; hence the induction ports needs to be blocked to prevent any leakage of air. This port has been blocked off between the combustion chamber and fuel chamber by using a thin 1 mm aluminium plate. For additional protection from leakage m-seal has been applied to prevent losses as far as possible. Compressed air will be able to extract maximum work only when it will be above the piston at the TDC. The most ideal place for induction would be in place of the spark plug. As there would be noneed of the spark plug and removing that will leave a big hole, which is needed to be filled.Hence, this becomes the most ideal place for entry of air. Using proper connectors, compressed air is induced directly from the top.

The timing circuit is the most crucial component of the entire air engine functioning[2]. This will determine the exact position of the piston where the air will be induced and for the time duration it needs to be supplied. This is accomplished by using proper sensors and a controller. For the experiment IR (infrared) sensors with varying range have been used. There are two sensors used. One to switch on the air supply and the other to shut off air supply. It is mounted on the shaft in such a way that the first sensor on the S-shaped plated is sensed just after the piston crosses the TDC. The IR sensor is connected to the controller. The Arduino kit collects the signals from both the sensors and relays the information to the solenoid valve for its operation. The Arduino kit itself can only manage voltages up to 5 V. For this reason motor driver to manage the high voltages and function as per the programming of Freeduino (Arduino) board is utilized[8].

The motor driver is connected to the battery which is responsiblefor the supply of voltage to IR sensors as well as the solenoid valve. The Arduino board receives the signal from the sensor and signals the solenoid valve to switch on and off. IR sensors are connected to both, the motor driver which will supply the required current and to the controller board to which it is supply the sensed signal[9]. The motor driver is connected to the solenoid valve as well. The Arduino which received the signal from the sensors are relayed to the motor driver which read the signal and supply power to solenoid valve. The connections of this timing circuit are as shown in the table I[8].

TABLE I CIRCUIT CONNECTIONS

From	To
Battery+	MD-12V
MD-5V	AB-5V
MD-5V	IR1,2-Vcc
MD-GRND	AB-GRND
MD-GRND	IR1,2-GRND
MD-ENA	AB-7
MD-N1	AB-8
MD-N2	AB-9
AB-3	IR1-OUT
AB-4	IR2-OUT
MD-OUT+	SOLENOID+
MD-OUT-	SOLENOID-
*Above connections are based on Arduino Uno R3 and LN298 Motor driver	

The main objective was to check the performance of engine for mobile use hence special storage tanks are required for air, but here it was for experimental purpose, so compressed air obtained directly from a compressor is used[1]. The air from the compressor is supplied at a certain pressure. An initial push is needed to start the engine as an exciter is not connected. The compressed air will then take over for supplying power. This air is supplied to the solenoid valve. For experimental analysis of the engine, pressure of compressed air and angular velocity obtained at the shaft need to be measured. A tachometer was used to measure the shaft speed. The readings were taken for variable pressure after allowing the pressure to stabilize. Further calculations for engine performance were done based on this values obtained.

Mathematical Modelling

For the calculation the atmospheric conditions are taken as standard temperature and pressure and the tank temperature is taken the same as atmospheric. The expansion of gases is assumed to be polytrophic [7].
In the Figure 2,
Process 1 to 2: Polytrophic Expansion of air
Process 2 to 3: Isobaric Compression of air

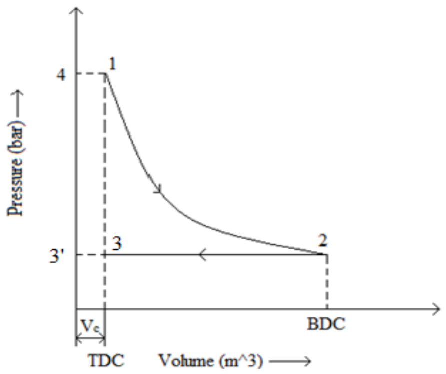


Fig.2P-V Diagram

Calculations

Assuming the dimension of a tank having dimensions:

Length of tank (l_t) = 1 m, Diameter of tank (d_t) = 0.5 m

Volume of tank (V_t) $= \frac{\pi}{4} d_t^2 l_t$

$= 0.1963 \ m^3$

Swept volume (V_s)

$$= \frac{Angle\ between\ TDC\ and\ EPO}{Angle\ between\ TDC\ and\ BDC} \times volume\ of\ combustion\ chamber = \frac{100}{180} \times 40$$

= 22.22 cc

This is the volume of air required for one rotation of the shaft. So, from this we can calculate the number of maximum rotations possible from a tank of the above specified capacity assuming it has enough pressure to move the piston.

Number of rotations possible (r) $= \frac{Volume\ of\ tank}{Swept\ Volume}$

= 8836 rotations

Assuming a wheel diameter (d_w) of 0.5 m, we can get the range and velocity of the vehicle

Range of the vehicle (R) $= \pi\, d_w\, r$

= 11.1439 km

For calculating velocity we will need run time of the engine. Run time will change with change in pressure.

Run Time (t) $= \frac{Number\ of\ revolutions}{Angular\ velocity}$

$= \frac{8836}{595}$ = 14.85 minutes

= 891 s

Velocity of vehicle (v) $= \frac{R}{t}$

$$= \frac{(13.873)(60)}{14.85}$$

$$= 56.038\ km/h = 15.57\ m/s$$

III. RESULT & DISCUSSION

As it can be very distinctly observed from the table II, with the decrease in pressure, the angular velocity measured at the shaft decreases. Here, runtime is the duration for which the air will last to give power to the shaft. Number of revolutions will remain the same as the volume utilized will be the same. Hence the distance travelled will be the same. So, the time within which the air is utilized will change. Higher the pressure, more will be the rotational speed, hence the same distance will be travelled in lesser time.

TABLE II EFFECT OF PRESSURE ON RANGE AND VELOCITY

Pressure	Angular Velocity	Number of revolutions	Run Time	Distance*	Velocity
Bar	RPM		sec	m	m/s
11	595	8836	891	13870	15.57
10.5	580	8836	913.8	13870	15.17
10	570	8836	930	13870	14.91
9	550	8836	963.6	13870	14.38
*Assuming diameter of wheel=0.5m					

This is clearly depicted in the figure 3 which shows an increasing trend for runtime for the decrease in the pressure. From the simple relation between time and distance, we can know that for the same distance, if the distance travelled is same, with increasing time, velocity will decrease[5]. This is seen from figure 4.

Experimentation on the modified engine yields many results. When it is not possible to maintain the pressure inside the tank, there will be a pressure drop as air is utilized. There will be

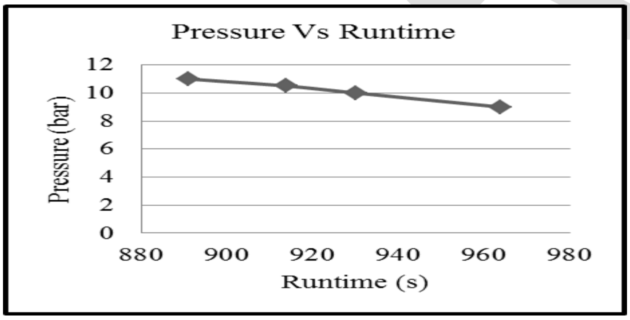


Fig.4 Pressure vs runtime chart

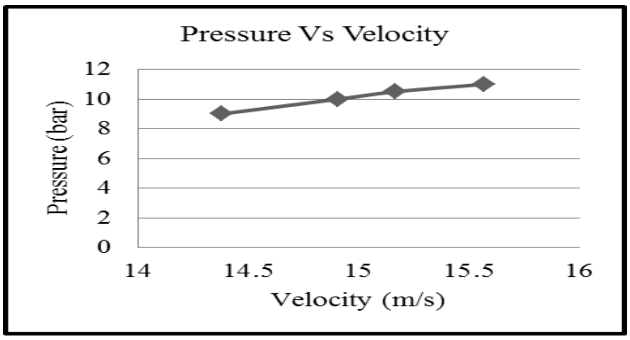


Fig.4 Pressure vs velocity chart

a decrease in the distance travelled by a considerable amount. Due to pressure drop, the velocity at each stage will also change and the average velocity will become nearly half of the maximum velocity at maximum pressure for this experimental analysis. The engine performance parameters change with the change in pressure[4]. A change in the tank pressure will affect the tank isothermal capacity and the work obtained at shaft. Lower the pressure, lower will be the work done. Similar trends will be seen in the power output and torque available at shaft and consequently the efficiency too.

REFERENCES

[1]. Patel, B. S., Barot, R. S., Shah, K., Sharma, P. 2011 "Air Powered Engine". National Conference on Recent Trends of Engineering and Technology.

[2]. Shen, Y &Hwang, Y. 2006 "Design and implementation of an air-powered motorcycle". Applied Energy; 86: 1105-1110.

[3]. Robinson T. 1997. Electric and hybrid vehicle technology. UK: International Press.

[4]. Verma, S. S. 2008 "Air Powered Vehicles". The Open Fuels and Energy Science Journal; 1:54-56.

[5]. Huang, K. D.,Tzeng, S. C., Chang, W. C.2005 "Energy-Saving Hybrid Vehicle using Pneumatic-Power System". Applied Energy; 81: 1-18.

[6]. Huang, K. D., Tzeng S. C., Ma W. P., Chang W. C. 2005 Hybrid pneumatic-power system which recycles exhaust gas of an internal-combustion engine. Applied Energy; 82:117–32.

[7]. YunusCengel, Michael Boles. Thermodynamics: An Engineering Approach, Seventh Edition, Tata McGraw Hill; 2010

[8]. From Arduino.cc, what is Arduino? (accessed February 2015) http://arduino.cc/en/Guide/Introduction

[9]. From azosensors.com, The A to Z of sensors, Infrared Sensors, (accessed March 2015) http://www.azosensors.com/Article.aspx?ArticleID=339