

Design and Development of Pneumatic Actuated Vehicle

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ABSTRACT: In present world the problem of pollution and continuous use of fossil fuels is a major concern. Since the non renewable resources are getting exhausted continuously and adding to that with increasing use there is an increase in pollution levels, damaging the environment and human health. So in such an environment use of renewable resources becomes need of the hour. Looking at the same context, through this paper we have tried to develop a pneumatic actuated vehicle which works through use of naturally available air fulfilling the idea of a clean energy system.

KEYWORDS: Compressor, double acting cylinder, solenoid valve, slider crank mechanism

I. INTRODUCTION

In a pneumatic system, the working fluid is a gas (mostly air) which is compressed above atmospheric pressure to impart pressure energy to the molecules. This stored pressure potential is converted to a suitable mechanical work in an appropriate controlled sequence using control valves and actuators. Conversion of various combinations of motions like rotary-rotary, linear-rotary and linear-linear is possible. The simplicity in design, durability and compact size of pneumatic systems make the well suited for mobile applications. Pneumatic control system plays very important role in industrial system owing to the advantages of low cost, easy maintenance, cleanliness, readily available, and cheap source, etc. A particularly well suited application for vehicle operating on compressed air is material handling and for visitors in industry.

Compressed air storage energy (CASE) is a promising method of energy storage, with high efficiency and environmental friendliness. Compressed air is regarded as fourth utility, after electricity, natural gas, water and the facilitating production activities in industrial environment. Unfortunately production of compressed air solely for pneumatic vehicle is not affordable but in manufacturing industries compressed air is widely used for many applications such as cooling, drying, actuating and removing metal chips. In addition, as a form of energy, compressed air represents no fire or explosion hazards; as the most natural substances, it is clean and safe and regarded as totally green. The performance of air car, in which the importance of the impact of the fossil fuels in the present and future generations has led to design a new vehicle which runs by renewable energy sources. Compressed air vehicle are more suitable for low speed, short range and flammable environment. An inventor, JemStansfield, has been able to convert a regular scooter to a compressed air moped. The moped has top speed of about 18 mph and could go 7 miles before its air pressure ran out. During literature survey it is observed that compressed air vehicles has many potential advantages over electric vehicles which includes no degradation problems of batteries, time required for refuelling the tank, easy disposal of compressed air tank without causing any pollution as with the batteries. Hence in order to overcome the above stated problems there is a need of eco-friendly vehicles using compressed air as a working medium in future. In

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

this work a sincere effort is made to develop Vehicle operating on compressed air by inversion of slider crank mechanism.

II. RELATED WORK

In 1903, the Liquid Air Company located in London England manufactured a number of compressed-air and liquefied-air cars. The major problem with these cars and all compressed-air cars is the lack of torque produced by the "engines" and the cost of compressing the air

The first compressed air vehicle was established in France by a Polish engineer Louis Mekarski in 1870. It was patented in 1872 and 1873 and was tested in Paris in 1876. The working principle of Mekarski's engine was the use of energy stored in compressed air to increase gas enthalpy of hot water when it is passed through hot water. Another application of the compressed air to drive vehicles comes from Uruguay in 1984, where Armando Regusci has been involved in constructing these machines. He constructed a four-wheeler with a pneumatic engine which travelled 100 km on a single tank in 1992. The Air Car was developed by Luxembourg-based MDI Group founder and former Formula One engineer Guy Negre in which works on a compressed air engine (CAE). He developed a compressed air- 4- cylinder engine run on air and gasoline in 1998 which he claims to be zero pollution cars. It uses compressed air to push its pistons when running at speeds under 35 mph and at higher speeds of 96 mph, the compressed air was heated by a fuel (bio fuel, gasoline, or diesel), due to which the air expanded before entering the engine. A fuel efficiency of about 100 mpg was observed.

Prof. B.S. Patel et al. tried to develop a compressed air engine by modifying an 4-stroke, single cylinder SI engine by replacing the spark plug with a pulsed pressure valve, and using compressed air as the working fluid. The working of the engine is explained theoretically and the cost analysis is made which shows that the compressed air engine is cheap when compared to the conventional SI engine.

Dr. Bharat Raj Singh and Dr. Onkar Singh conducted an experiment in which they used a vane type novel air turbine as a prime mover for a motor bike. In this experiment they tried to gain an output of 6.50 to 7.20 HP for the starting torque requirements of 500 to 750 rpm at 4 to 6 bars air pressure to running speeds of 2000 to 3000 rpm using 2 to 3 bars air pressure. The test was conducted in HBTI Kanpur. It consisted of an air compressor which was used to produce and store 300 psi (21 bars approx.) Air and use it to impact the compressed air on the vanes of the novel air turbine. The test was conducted at different inlet pressures and the efficiencies of the turbine were found to vary from 72 to 97 %.

Edwin Yi Yuan, a 23-year-old student at RMIT (Royal Melbourne Institute of Technology), worked on the group project in an industrial design course. The engine used to grind this machine is an invention of a Melbourne based engineer, Angelo Di Pietro. It is lightweight and runs on air compressed from two compressed air tanks on the bike. It revs up 10,000 RPM thereby eliminating the need of a gearbox, bringing only a single gear into use.

III. PNEUMATIC ACTUATED VEHICLE

The concept of a pneumatic actuated vehicle is shown here, where a compressor is running through a battery. The compressor is connected to a tank, from the tank through the pressure gauge the tank is connected to a solenoid valve for actuation of a double acting pneumatic cylinder which controls the movement of the slider crank. From the slider crank the drive is given to the wheels and the motion is obtained.

The following figure shows the conceptual diagram of a pneumatic actuated vehicle.

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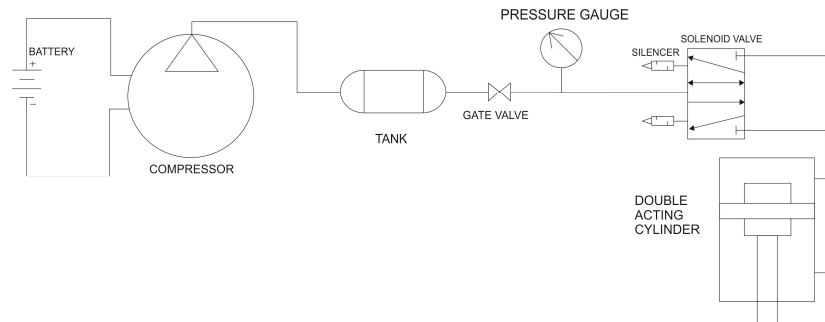


Figure No.1, showing block diagram of the conceptual pneumatic actuated vehicle

IV. DESIGN OF VEHICLE & FABRICATION

Force exerted by double acting pneumatic cylinder during out stroke can be expressed as the given equation:

$$F = P \cdot A$$

Where, F = Force exerted (in N)
P = Gauge Pressure (in N/m² or Pascal)
A = Full bore area
d = Full bore piston diameter (m)

Assuming the following values for our simulation,

$$P = 5 \text{ bar} = 500 \text{ kilo Pascal}$$

$$d = 50 \text{ mm} = 0.05 \text{ m}$$

$$F = 500 \cdot \pi \cdot (0.05)^2 / 4$$

$$F = 0.982 \text{ KN}$$

$$F = 100 \text{ kg} \quad [1 \text{ N} = 0.102 \text{ kg}]$$

The force exerted by double acting cylinder during in stroke can be expressed as :

$$F = P \cdot \pi \cdot (d_1^2 - d_2^2) / 4$$

Where, d₁ = Full bore piston diameter (m) = 0.05 m
d₂ = Piston rod diameter (m) = 0.015 m
P = 500 KPa
 $F = 500 \cdot \pi \cdot (0.05^2 - 0.015^2) / 4$
F = 0.893 KN
F = 91.1 Kg

Mean piston speed = engine speed / stroke
= 60/125
= 0.48 m/s

Volume of air displaced by the piston

$$V \text{ (out stroke)} = \{ (\pi \cdot D^2) / 4 \} \cdot s \cdot (P_s + P_a) / P_a \cdot 10^{-6}$$

$$V \text{ (in stroke)} = \{ \pi \cdot (D^2 - d^2) / 4 \} \cdot s \cdot (P_s + P_a) / P_a \cdot 10^{-6}$$

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Where, D = cylinder bore diameter (mm)
d = rod diameter (mm)
V = volume of free air (dm³)
S = stroke (mm)
Ps = supply gauge pressure (Bar)
Pa = atmospheric pressure (assumed to be 1 bar)
(Ps+Pa)/Pa = compression ratio

$$V \text{ (out stroke)} = \pi \cdot (50)^2 / 4 \cdot 125 \cdot (5+1) / 1 \cdot 10^{-6} \\ = 1.47 \text{ dm}^3$$

$$V \text{ (in stroke)} = \pi \cdot (50^2 - 15^2) / 4 \cdot 125 \cdot (5+1) / 1 \cdot 10^{-6} \\ = 1.34 \text{ dm}^3$$

PISTON TRAVEL Vs CRANK ROTATION

The ratio of rod to stroke length should be between 1.2 to 2.2

$$\text{RATIO "n"} = \text{Rod Length} / \text{Stroke} \\ = 150 / 125 \text{ mm} \\ = 1.2 \text{ mm}$$

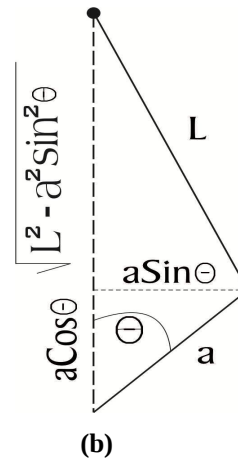
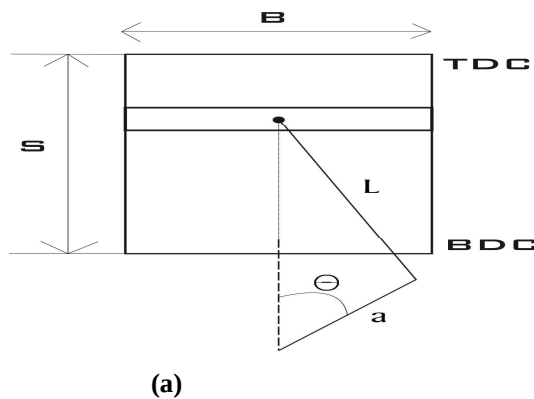


Figure No.2, (a) showing piston stroke and (b) shows the rotation of crank through angle θ

Where:

TDC and BDC = Top Dead Centre and Bottom Dead Centre

B = Bore (i.e., diameter of the cylinder)

L - Length of the connecting rod = 150 mm

S - Stroke length = 125 mm

a - Crank radius = 52 mm

θ - Crank angle

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Where, $\sin\theta = (\text{Stroke}) / (\text{Rod length} \times 2)$

$$\theta = \sin^{-1}[(125)/150 \times 2]$$

$$\theta = 24.6^\circ$$

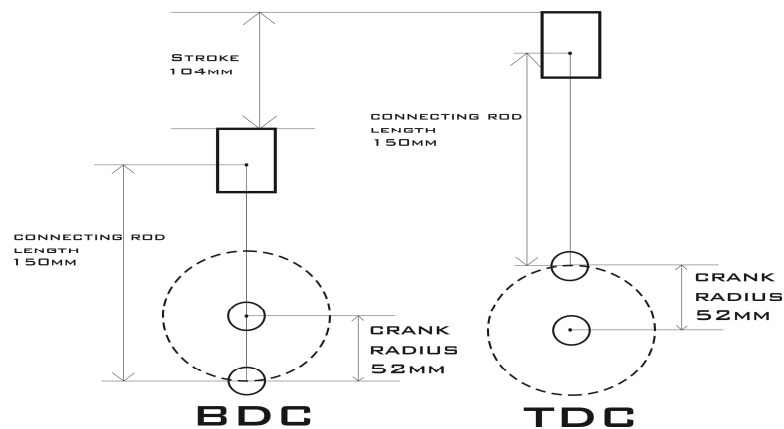


Figure No. 3, shows the rotation of crank wrt. to TDC and BTC Position of the cylinder

If the crank rod has turned 90° after TDC as shown, a right angle is formed by crank radius.

If the value 'X' is subtracted from the length of the connecting rod plus crank radius, the distance moved by the piston can be obtained.

$$\text{Piston Displacement} = 202 - 140.7$$

$$\text{Piston Displacement} = 61.3\text{mm}$$

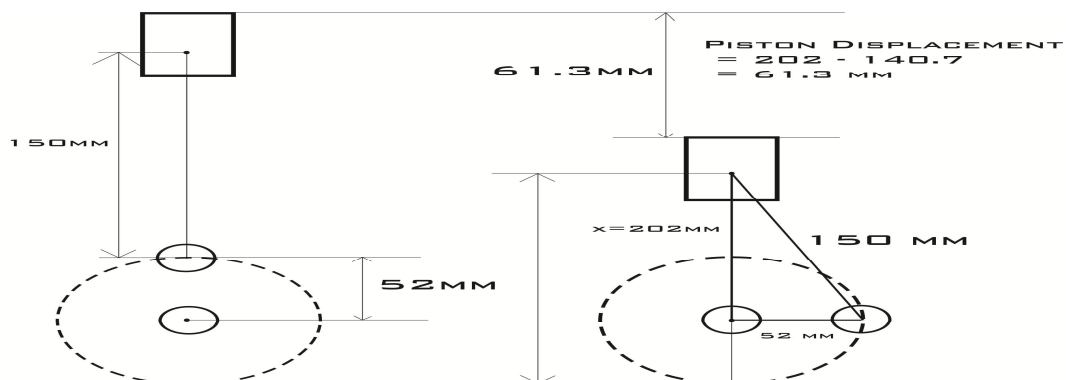


Figure No. 4, shows the piston Displacement

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Data considered for the theoretical calculations are given below:

Gross Vehicle Weight (GVW) = 27Kg
Weight of each drive wheel = 9Kg
Radius of the Wheel (R_w) = 80mm
Desired top speed = V_{max} = 5Km/Hr = 1.389 m/sec
Desired Acceleration Time = 2 seconds
Maximum Incline Angle = 2°
Worst Working Surface = Concrete

To Calculate the Torque which is enough to propel the vehicle, it is necessary to determine Total Tractive Force (TTE)

$$TTE = RR + GR + FA$$

Where,

RR = Force necessary to overcome rolling resistance (Kg)

GR = Force required to climb a grade (Kg)

FA = Force required to accelerate to final velocity (Kg)

To Calculate RR (Rolling Resistance)

$$\begin{aligned} RR &= GVW \times C_{rr} \\ C_{rr} &= \text{Surface Friction} = 0.04 - 0.08 \text{ (Teflon Material)} \\ &= 27 \times 0.04 \\ \mathbf{RR} &= \mathbf{1.08 \text{ Kg}} \end{aligned}$$

To Calculate GR (Grade Resistance)

$$\begin{aligned} GR &= GVW \times \sin \alpha \\ &= 27 \times \sin 2^\circ \\ \mathbf{GR} &= \mathbf{0.94228 \text{ Kg}} \end{aligned}$$

To Calculate Acceleration Force (FA)

$$\begin{aligned} FA &= (GVW \times V_{max}) / (9.8 \text{ m/s}^2) \times t(a) \\ \text{Where, } 9.8 \text{ m/s}^2 & \text{ is Acceleration due to gravity, } g \\ &= (27 \times 1.389) / (9.8 \times 2) \\ \mathbf{FA} &= \mathbf{1.9134 \text{ Kg}} \end{aligned}$$

Hence,

$$\begin{aligned} TTE &= RR + GR + FA \\ &= 1.08 + 0.94228 + 1.9134 \\ \mathbf{TTE} &= \mathbf{3.9356 \text{ Kg}} \end{aligned}$$

Now,

$$\text{Wheel Torque (Tw)} = TTE \times R_w \times R_F$$

Where, R_F = Resistance factor, Typical values range between 1.1 and 1.15

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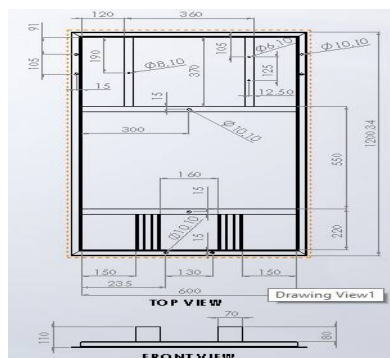
$$= 3.9356 \times 0.08 \times 1.1$$

Wheel Torque (T_w) = 0.3464 Kg-m
Torque in terms of N-m, multiplying with 9.8
Wheel Torque (T_w) = 0.3464 x 9.8
Wheel Torque (T_w) = 3.39 N-m

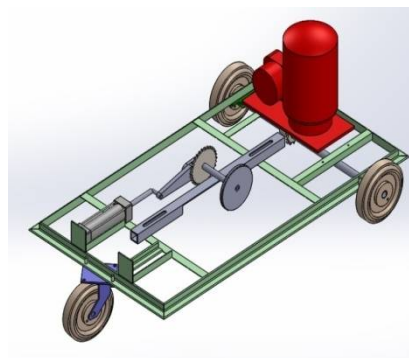
Sl. No.	Components Involved In Vehicle design	Theoretical Values
1.	Force Exerted by cylinder Piston during outward stroke	100.0kg
2.	Force Exerted by cylinder Piston during inward stroke	91.10kg
3.	Mean Piston Speed	0.4m/s

Table No.1, showing the theoretical values of components required to propel the vehicle

CHASSEY DESIGN



(a)



(b)



(c)

Figure No. 5, (a) showing the chassey design, (b) shows the chassey model developed using CATIA, (c) shows fabricated model

WORKING

The Compressor is switched ON, powered by a 8-12 Amp battery which produces a pressure of 5 bar .The pressurized air is stored in the storage tank (6 litres) through the hose pipes. This air is supplied to the pneumatic drive to actuate the system through solenoid valve controller (5/2 = 5 way and 2 positions) which consist of 1-inlet port, 2-cylinder ports and 2-exhaust ports fitted with mufflers to reduce the noise. The mufflers or silencers are also used to control / regulate the speed of the air flow to the double acting cylinder. This setup is semi-automated by means of electronics, which is controlled or operated by means of Bluetooth signals at proper interval of time .The connecting rod connects the pneumatic drive head and the crank shaft. The controlled air flow is supplied to the double acting cylinder through hose pipe. The valve timing is set and controlled by the solenoid valve. The slide crank mechanism enables the crank to gain rotary motion, this rotary motion is supplied to the sprocket using chain drive. This powers the rear wheel to produce motion.

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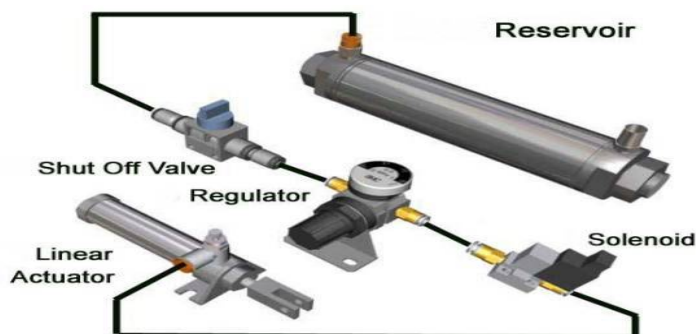


Figure No.6, shows the actuating mechanism of the vehicle

V. CONCLUSION

This project explores the effective application of pneumatic power. Pneumatic vehicle will replace the battery operated vehicles used in industries. Pneumatic powered vehicle requires very less time for refuelling as compared to battery operated vehicle. This is totally clean, light weight circuit, can work in hazardous environment and requires less maintenance. Hence the scope of Pneumatic actuated vehicles in the future is huge and further research in this field can yield more convincing results.

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