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Fabrication and Testing of Compressed Air Car Viswanadha Institute of Technology and Management

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Though some of the renewable energy sources like solar energy, bio fuels are currently in practice, we focused on *pneumatic technology*. Since pneumatic applications are wide all over the world, basic components and other equipment are easily available and the fabrication is not so tough. The basic principle involved in this concept is that compressed air is capable enough to provide sufficient thrust which in turn can propel the car. This report is a detailed description of the fabrication, working and testing of the compressed air car.

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I. Introduction

Fossil fuels (i.e., petroleum, diesel, natural gas and coal), which meet most of the world's energy demand today, are being depleted rapidly. Also, their combustion products are causing global problems, such as the greenhouse effect, ozone layer depletion, acid rains and pollution, which are posing great danger for our environment, and eventually, for the total life on our planet. These factors are leading automobile manufacturers to develop cars propelled by alternative energies. Hybrid cars, Fuel cell powered cars, Hydrogen fueled cars will be soon into the market as a result of it.

One possible alternative is the *Air-Powered Car*. Air, which is abundantly available and is free from pollution, can be compressed to higher pressures at a very low cost, is one of the prime option since Whereas so far all the attempts made to eliminate the pollution has however reduced it, but complete eradication is still rigorously pursued. Compressed air utilization in the pneumatic applications has been long proven. Air motors, pneumatic engines, actuators and other equipments are in use. Compressed air was also used in some of the vehicle for boosting the initial torque.

Compressed air has been used since the 19th century [10] to power mine locomotives, and was previously the basis of naval torpedo propulsion. The major problem with this car is the lack of torque produced by the "engines". The costs involved to compress the air to be used in a vehicle are inferior to the costs involved with a normal combustion engine. Air is abundant, economical, transportable, storable and, most importantly, nonpolluting. The technology involved with compressed air reduces the production costs of vehicles with 20% because it is not necessary to assemble a refrigeration system, a fuel tank, spark plugs or mufflers. Air itself is not flammable.

The mechanical design of the motor is simple and robust. The tanks used in an air compressed motor can be discarded or recycled with less contamination than batteries. The tanks used in a compressed air motor have a longer lifespan in comparison with batteries, which, after a while suffer from a reduction in performance. Refueling can be done at home using an air compressor or at service stations. Reduced vehicle weight is the principle efficiency factor of compressed-air car. The rate of self-discharge is very low opposed to batteries that deplete their charge slowly over time.

Therefore, the vehicle may be left unused for longer periods of time than electric cars. Lower initial cost than battery electric vehicles when mass produced.

Compressed air is not subject to fuel tax. Lighter vehicles would result in less wear on roads. The price of fueling air powered vehicles may be significantly cheaper than current fuels.

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II. Comparative Study

Comparison of several types of green car basic characteristics (Values are overall for vehicles in current production and may differ between types)				
Type of vehicle/ power train	Fuel economy (mpg equivalent)	Range	Production cost for given range	Reduction in CO_2 compared to conventional
Conventional ICE	10-78	Long (400-600 mi)	Low	0%
Biodiesel	18-71	Long (360-540 mi)	Low	100%
All-electric	battery	Shorter (73-150 mi)	High	varies
Compressed air	30-60	380 mi	Medium	100 %

[1-4]

III. Other Developments in Compressed Air Car Technology

Currently some new technologies regarding compressed air cars have emerged. A Republic of Korean company has created a pneumatic hybrid electric vehicle car engine that runs on electricity and compressed air. The engine, which powers a pneumatic-hybrid electric vehicle (PHEV) [10][13], works alongside an electric motor to create the power source. The system eliminates the need for fuel, making the PHEV pollution-free. The system is controlled by an ECU in the car, which controls both power packs i.e. the compressed-air engine and electric motor. The compressed air drives the pistons, which turn the vehicle's wheels. The air is compressed, using a small motor, powered by a 48-volt battery, which powers both the air compressor and the electric motor. Once compressed, the air is stored in a tank. The compressed air is used when the car needs a lot of energy, such as for starting up and acceleration. The electric motor comes to life once the car has gained normal cruising speed. The PHEV system could reduce the cost of vehicle production by about 20 per cent, because there is no need for a cooling system, fuel tank, spark plugs or silencers.

IV. How Compressed Air can Drive a Car

The laws of physics dictate that uncontained gases will fill any given space. The easiest way to see this in action is to inflate a balloon [13]. 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 car move.

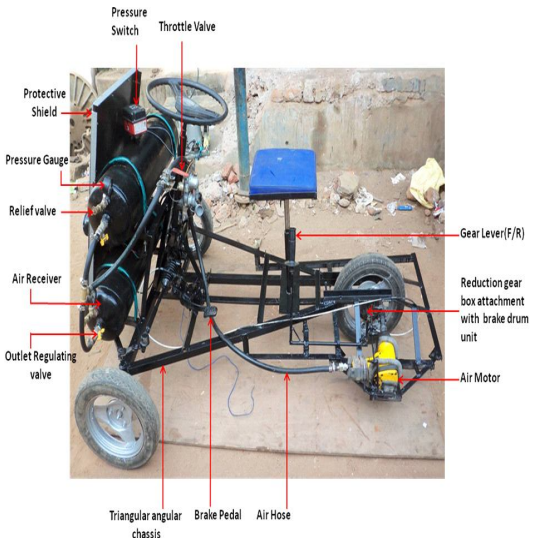

Figure 1 : Layout of Compressed Air Car

Air car will have air compressor built into it. After a brisk drive, we can 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 few minutes 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.

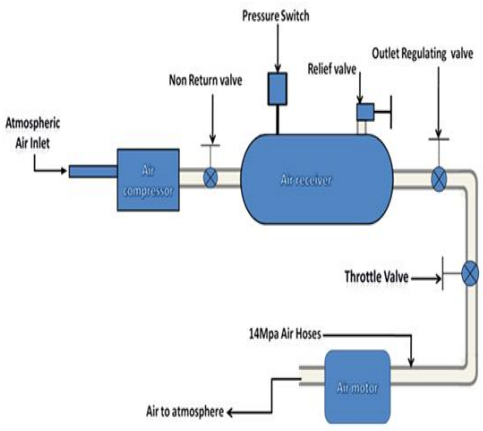

Figure 2 : Line Diagram of Compressed Air Car

This air car will almost certainly use *Compressed Air Motor (CAM)/ Pneumatic wrench.* Air car propelled with this engine will have tanks that will probably hold compressed air to about 11.03bar pressure. Its accelerator operates a valve on its tank that allows air to be released into the hoses and then into the motor, where the pressure of the air's expansion will push against the vanes and turn the rotor. This will produce enough power for speeds of about 15-20 kilometers per hour.

V. Work Division into Sub Assemblies

The entire work is categorized into 5 phases. Each phase consists of a series of operations followed by the next phase. Several changes were made in the design depending upon the physical stability of the car.

a) Preparatory Work

Detailed study of the project, formulating the methods, Design preparation, abstract preparation, project formulation.

b) Sub Assembly 1

Parts accumulation, inspecting the components, pre-processing of components.

c) Sub Assembly 2

Pre-processing of the prepared design.

d) Sub Assembly 3

Fabrication, Painting, Testing.

e) Sub Assembly 4

Evaluation.

VI. Technical Specifications

1. Compressor
2. Reciprocating compressor
3. Single stage
4. Hermetically sealed
5. 1.5 HP, 3000 rpm

Table 6.2 : Overall Dimensions

Component	Dimension in mm
Wheel rim diameter	280
Wheel diameter	380
Wheel width	75
Front track length	1070
Ground clearance	280
Tank thickness	3
Bearing OD	35
Bearing ID	15
Bearing thickness	10

Table 6.3 : Details of Compressed Air Car

Input power consumption	79.2 Watts
Time of filling(for 2 cylinders)	6 minutes
Cost of filling(@unit charge 5/-)	Rs. 0.32
Air consumption	340 l/min
Cylinder storing pressure	11.03bar
Working pressure	6.2bar
Cylinder storing capacity each	38lts
Output power	2.169 kW

Table 6.4 : Specifications of Air Motor

Idle speed	4500 rpm
When connected to wheel	1650 rpm
On load speed	300 rpm
Weight	4.5 kgs
Torque	677 N-m
Air inlet (PT)	1/4 inch
Air Hose (ID)	3/8 inch

VII. Chassis Design Parameters

Chassis Fabrication: Chassis is made by triangular angular incorporating arc welding at various sections. It includes:

1. Lap joint welds
2. Butt welds
3. T joint welds.

The end joints are butt welded and some internal angular sections are lap welded. The steering column support is given by welding a hollow shaft with a T weld to the front frame of the chassis.

a) Wheel Mounting

After the completion of chassis, wheels are mounted; two on the front side and one on the rear side. Inclination is provided between the front and rear side of the chassis frame for steering compensation.

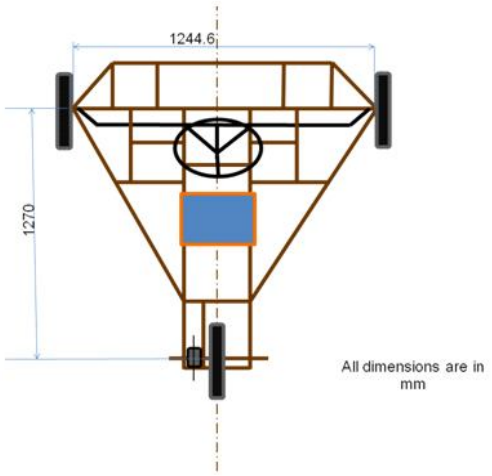

Figure 3 : Frame Model of Compressed Air Car

b) Rear Wheel Settings

The rear wheel is given priority because power drive and braking system are given to this wheel. The wheel spindle is aligned with the wheel centre. This is given supports on either side of the wheel. The spindle is extended on either side of the wheel. One side is for power transmission compensation and the other side is for brake setup compensation. Rests of the components are mounted on the chassis at the requisite positions according to the design parameters. A number of modifications were done in the design during the tests performed after installation of each and every module.

VIII. Pressure Cut off Switch

This is a device designed to monitor a process pressure and provide an output when a set pressure (set point) is reached. A pressure switch does this by applying the process pressure to a diaphragm or piston to generate a force which is compared to that of a pre-compressed range spring.

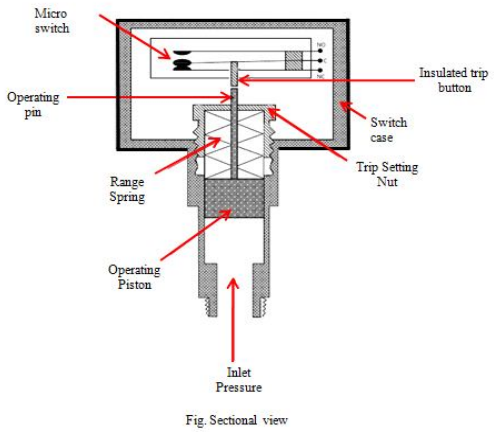

Figure 4 : Sectional view of Pressure Switch

A pressure switch is used to detect the presence of fluid pressure. Most pressure switches use a diaphragm or bellow as the sensing element. The movement of this sensing element is used to actuate one or more switch contacts to indicate an alarm or initiate a control action. Pressure switches have different designs with different sensing elements. One of the most common is the one with diaphragms or bellows as the sensing elements. The one I will discuss here uses a piston as the pressure sensing element. In any case, the operating principle for this piston type is the same with a diaphragm or bellow type pressure switch.

IX. Rotary Vane Air Motor

A pneumatic motor or compressed air engine is a type of motor which does mechanical work by expanding compressed air [10]. Pneumatic motors generally convert the compressed air 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 kilo Watts. 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

Figure 5 : Pneumatic Motor

expand their use to the transportation industry. Pneumatic actuation is commonly used in industrial and commercial applications for its low cost, compact size, high power-to-weight ratio, reliability, and low maintenance. In many cases, these characteristics make it preferable over electric actuation, especially when a supply of air is readily available. The major limitation of classic pneumatic actuators, rotary or linear, has been their reduced precision in controlled motion. This is mainly caused by air compressibility and friction in the valve and actuator, which make the pump-line-actuator dynamic system highly nonlinear. Novel hardware and pneumatic servo control solutions have been proposed to cope with these problems, and impressive results have been achieved in force control and speed regulation. Nevertheless, these complex solutions require special care, and so most practical applications are still limited to unregulated pneumatic motion. However, pneumatic motors must overcome inefficiencies before being seen as a viable option in the transportation industry.

Rotary Vane Air motors feature durable construction with precision heavy-duty bearings throughout, and multiple blade rotors for smooth power. There is a wide range of speeds and torques as well as a choice of foot, face, or flange mounting. These motors require air line lubrication for long, trouble-free service. Mount the lubricator as close to the motor as possible. These motors perform satisfactorily in high temperature areas up to 200°F *(93° C)* [7].

X. Power Transmission

The power transmission undergoes the following processes. Air is stored in the tank at a pressure of 11.03bar. From the tank, air flow is synchronized by a regulator. This maintains pressure to the downstream

Figure 6 : Entire View of Power Transmission

Components as long as there is a pressure difference between the reservoir and the required operating pressure. Controlled discharge from the tank is proportional to the release of butterfly valve. From there, air is boosted to the pneumatic wrench inlet. Hence this compressed air expands at the rotor blades where its pressure energy is converted to rotational energy of the rotor. Ultimately spindle connected to the rotor is given drive in turn is given to the rear wheel.

XI. Braking System

a) Principle of Braking System

While operating the braking system the kinetic energy of the moving vehicle is converted into heat energy.

b) Drum Brakes

The concept here is simple, two semicircular brake shoes sit inside a spinning drum which is attached to the wheel. When you apply the brakes, the shoes are expanded outwards to press against the inside of the drum. This creates friction, which creates heat, which transfers kinetic energy, which slows you down. As the brakes are applied, the cable which is connected to one end of the lever is pulled and the other end transfers the forces against the brake shoes and in turn forces them to expand outwards. The return spring is what pulls the shoes back away from the surface of the brake drum when the brakes are released. This is the simple working of the braking system which is incorporated in Compressed Air Car for easy halt of the vehicle because of the low speed ranges.

Fig 7 : Brake Dru

Fig 8 : Brake Pedal

XII. Steering System

Like most things in a car, the concept of steering is simple -you turn the steering wheel, the front wheels turn accordingly, and the car changes direction. How that happens though is not quite so simple. So for our project Compressed Air Car we used Rack And Pinion type Steering System. In a rack and pinion

Figure 9 : Steering linkages

System, toothed bar with the tie rods attached to each end. On the end of the steering column there is a simple pinion gear that meshes with the rack. When you turn the steering wheel, the pinion gear turns, and move the rack from left to right. Changing the size of the pinion gear alters the steering ratio. This steering mechanism follows the Ackerman's Steering Principle which is very best suited for our project to eliminate the weight of the vehicle because of the simple construction of the steering mechanism.

XIII. Suspension System

Figure 10 : Coil Spring

The suspension points of the vehicle for a chassis should be considered before the chassis itself. Suspension and all the chassis requirements will involve much compromise. For this text into consideration we thought of coil spring type of suspension. This is because the vehicle weight is so much optimized because of internal physics involving in the propulsion of the Compressed Air Car as well they store energy and subsequently releases it. These can easily withstand the weight excreted and avoid uneven forces on the tire causing loss of traction. It absorbs the shocks and disturbances created while the vehicle is in dynamic phase. This also protects the tanks which are stored with compressed air while the vehicle is passing through any ditches or bumps. This is the simple suspension system attached for Compressed Air Car.

XIV. Testing and Performance

a) Road Testing

Car was tested at various pressures of compressed air keeping the vehicle dynamics into consideration. Maximum permissible load was tested and the result depicted fair values.

Brake tests were conducted and the joint efficiencies were observed. They withstood the impacts and could resist the jerks.

b) Leak Testing

Leak testing is required by most codes prior to initial operation and each piping system must be tested to ensure leak tightness. The field test is normally a hydrostatic leak test. There are several other types of testing depending on service fluid and there are six different testing methods that can be used at most construction sites.

1. Hydrostatic testing which uses water under pressure.
2. Pneumatic testing which uses gas or air under pressure.
3. In-service testing which involves a walk down for leakage when the system is put into operation.
4. Vacuum testing which uses negative pressure to check for leakage.
5. Static head testing which is normally done for drain piping with water with a known static head pressure left in a standpipe for a set period of time.
6. Tracer leak method for inert gas leak detection.

c) Pneumatic Leak Testing

The fluid medium used for pneumatic testing is either compressed air or Nitrogen gas. The test pressure by code is usually 1.1 times the design line pressure. Pneumatic testing involves the potential hazard of releasing energy stored in the compressed gas. Care must be taken by gradually increasing pressure in steps up to the test pressure, holding only as long as the code requires, then reducing to the design pressure for inspection of the joints. The inspection of joints is done utilizing a soapy water mix that bubbles when air is escaping.

d) Soap solution test

This is one of the simplest and cheapest methods to spot the leaks in a pneumatic circuit. A soap solution is prepared and is applied at all the joints, fixtures of the hoses, valves, reservoir connections and other sensitive parts. This solution is applied after the tanks are filled to a rated level. All the valves are opened and air starts rushing through the connections. Whenever there is a leak present, with the movement of air molecules, soap bubbles start emerging at the leak spot. Thus the leak spot is observed.

XV. Safety features of the Air Car

a) The CATS air tanks store 0.036m3 of air at 6.8 bars of pressure (two tanks have a capacity of 78 liters, and they store 0.078 m3 of air at a pressure of 6.8bars), just like tanks already used to carry liquefied gases on some urban buses.
b) That means that the tanks are prepared and certified to carry an explosive product: methane gas. In the case of an accident with air tank breakage, there would be no explosion or shattering for the tanks that are not metallic but made of glass fiber.
c) The tanks would crack longitudinally, and the air would escape, causing a strong buzzing sound with no dangerous factor.
d) It is clear that if this technology has been tested and prepared to carry an inflammable and explosive gas, it can also be used to carry air.

XVI. Disadvantages

Just like the modern car and most household appliances, the principle disadvantage is that of indirect energy use. Energy is used to compress air, which - in turn - provides the energy to run the motor. Any indirect step in energy usage results in loss. For conventional combustion engine cars, the energy is lost when oil is converted to usable fuel - including drilling, refinement, labor and storage. For compressed-air cars, energy is lost when electrical energy is converted to compressed air. Once the tanks are exhausted, car cannot be driven until it is refilled at the nearest filling station.

XVII. Starting Procedure

1. Take the seating position.
2. Open the outlet valve of one cylinder.
3. Now slowly open the regulator and increase the air discharge.
4. Steer the vehicle properly.
5. Regulate the check valve gently and maintain the required speed.

6. When the air in a tank is exhausted close the corresponding valve and open the outlet valve of the parallel cylinder.
7. While applying the brakes, close the throttle valve (regulator) and then the pedal as to be applied.
8. While engaging and disengaging the forward and reverse gear the car is to be brought to rest (motor rpm=0) and then the direction is to changed.
9. Shut off the valves when not in use.

XVIII. Service Manual

a) Lubricate the following parts periodically

1. Front wheel bearings.
2. Rear wheel bearing.
3. Pneumatic motor.
4. Steering linkages.

b) Clean the following periodically

1. Pneumatic motor, wheels and universal joints.
2. Steering links.
3. Tanks.

c) Check all the valves periodically

d) Check all the fittings regularly

XIX. The Activities and Related Results of the Project

During the first phase of project, design parameters are considered and components are collected, processed and upgraded. During the second phase of project, research has been done and the prototype is brought to present stage by performing the above functions.

XX. Places

Our project is carried out in various sections. Some of the spares which were supposed to be machined to the required dimensions were fabricated by us at the Padmakar Engineering company workshop. The main assembly works, testing, and painting were done at our college premises.

XXI. Problems

This is a typical live project. Some of the problems associated with this project are;

1. Accumulation of accessories was the toughest job and elapsed more time.
2. Transportation problems: heavy components are requisite for this project. Their shipping was intricate.
3. Several mechanical operations were integrated which required trained persons for performing them.
4. Compressed air tank is a major component which requires strict attention, otherwise accidents may take place.
5. All assembly processes must be done perfectly and rigidly.

XXII. Conclusions

The technology of compressed air vehicles is not new. In fact, it has been around for years. Compressed air technology allows engines/ motors that are both nonpolluting and economical. After one year of research and development, our compressed air car is brought into existence. Unlike electric or hydrogen powered vehicles, compressed air car is not expensive. Compressed air car is affordable and have a performance rate whose power to weight ratio stands up to 0.0373kW/kg. For arriving at a fair power to weight ratio, we considered possible factors which would result to minimize the weight of the car. For this we designed 3 wheeled vehicle. The entire chassis is fabricated with 1 inch angular frames. Unlike conventional transmission systems which include clutch, counter shaft, fly wheel, propeller shaft, differential, our pneumatic motor is coupled to the rear wheel with intermediate gear box which greatly reduces the transmission losses and weight of the vehicle. It also occupies lesser space compared to a four wheeler. This car gives an economy of about Rs.1 per kilometer. At the same time the well to wheels efficiency of the vehicle need to be improved. This is a revolutionary design which is not only eco friendly, pollution free, but is also very economical. This addresses both the problems of fuel crisis and pollution. However excessive research is needed to completely prove the technology for both its commercial and technical viability. Our motto is to bring peace and tranquility to earth from pollution.

XXIII. Acknowledgements

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