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Design, Fabrication and Simulation of Compressed Air Hybrid Vehicle

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Abstract: *Compressed Air Hybrid Vehicle is powered by two forms of Energy such as Pneumatic and Electrical. Efforts are being made by many developers and manufacturers to have a developed vehicle technology. So the new age of vehicle such as hybrid vehicle is necessary. The Electrical energy is provided by means of solar cells to battery and then to the electric motor. In the Electric motor, Electrical energy is converted into mechanical energy which in turn is converted into kinetic energy. In the Pneumatic system, the working fluid is a gas which is compressed above atmospheric pressure to impact impart pressure energy to the molecules, such that pneumatic piston move front and back cause transverse motion which in turn is converted into kinetic energy by crank and chain mechanism.*

CAHV has zero emission and is ideal for city driving conditions. Although it seems to be an environment-friendly solution, one must consider its efficiency. Nevertheless, the compressed air hybrid vehicle will help to reduce urban air pollution in the long run. The working of a vehicle based on hybrid Energy make a change in both history as well as future. The CAHV has low weight, simple circuits, less time consumption for refueling and requires less maintenance will be the future means of best transportation.

Keywords: ***Pneumatic cylinder; Electrical Motor; Comparison of energy density with other fuels;Scope.***

I. Introduction:

In 1834, the first vehicle actually a tricycle, powered by battery, was developed. But with the improvement in the internal combustion engine (ICE), ICE vehicles (conventional vehicles) have occupied an absolute share in the market; pure electric vehicles (PEVs) have almost disappeared since 1930's[1]. The global population will increase from 6 billion in 2000 to 10 billion in 2050, and the global vehicles will increase from 700 million to 2.5 billion consequently. The fossil fuel engines which were good enough for us before 30-40 years but now they are one of the sources of contributor of global warming and pollution with fossil fuel crises.

If all vehicles are powered by internal combustion engines, the gasoline and diesel oil will be depleted quickly, and the emission will result in greenhouse effect. So, the energy conservation and environmental protection are growing concerns around the world. So the new age of vehicle such as hybrid vehicle is necessary. Environment protection and energy crisis have urged the development of hybrid vehicle. It is hard to believe that compressed air can be used to drive vehicles. However that is true, and the "air car", as it is popularly known, has caught the attention of researchers worldwide[2]. It has zero emissions and is ideal for city driving conditions. 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. 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 the vehicle move.

II. Literature Review:

[1].Felix Creutzig's journal about "On Economic and environmental evaluation of compressed-air cars". Res. Lett. 4044011.

Felix Creutzig explained how the compressed-air car is useful for the future based on Economic and environmental factors. Such that Climate change and energy security require a reduction in travel demand, a modal shift, and technological innovation in the transport sector. Through a series of press releases and demonstrations, a car using energy stored in compressed air produced by a compressor has been suggested as an environmentally friendly vehicle of the future. We analyze the thermodynamic efficiency of a compressed-air car powered by a pneumatic engine and consider the merits of compressed air versus chemical storage of potential energy.

[2].Prof. Kalpesh Chavda1 Patel & Mr. Manish "On Study and Development of Compressed Air Engine-Single Cylinder". International Journal for Scientific Research & Development| Vol. 2, Issue 05, 2014.

Prof. Kalpesh Chavda1 Patel & Mr. Manish details about reports on the review of compressed air engine for the design and development of single cylinder engine which can be run by the compressed air. Current four strokes single cylinder engine (bikes/moped) can be run on the compressed air with a few modifications that are the main objective of the study. Compressed air filled by electricity using a compressor. The electricity requirement for compressing air has to be considered while computing overall efficiency.

[3]. Mr. N.Govind , Mr.S.Sanyasi Rao & Mr.Manish kumar Behera "On Design and Fabrication of Compressed Air Vehicle".

International Journal & Magazine of Engineering, Technology, Management and Research ISSN No: 2348-4845. Mr. N.Govind , Mr.S.Sanyasi Rao & Mr.Manish kumar Behera discussed on Compressed air as a source of energy in different uses in general and as a nonpolluting fuel in compressed air vehicles has attracted scientists and engineers for centuries. Efforts are being made by many developers and manufacturers to master the compressed air vehicle technology in all respects for its earliest use by the mankind.

[4]. Mr. Kunjan Shinde IJRMET Vol. 7, Issue 1, Nov. 2016 - April 2017 Issn : 2249-5762 . Issn : 2249-5770 "On Electric Bike".

Mr. Kunjan Shinde's journal on Electric Bike describes the idea of harnessing the various energy and use it in today's existence of human life. Electric bike which will be driven with the help of battery and thus provide required voltage to the motor. The focus of this report is to perform power calculations and system design of this Electric Bike.

III. Design and Modelling:

The design and modeling consists of various parts and their assembling.

The Main components are:

1. Air Tank

A gas air tank is a mechanical device that increases the pressure of a gas by reducing its volume. Air tanks are similar to pumps: both increase the pressure on a fluid and both can transport the fluid through a pipe. The compressibility of the air was first investigated by Robot Boyle in 1962 and that found that the product of pressure and volumes of particular quantity of gas. The usual written as, PV =C (or) P1V1=P2V2. The tank may be able to be refilled more often and in less time, with refueling rates comparable to liquid fuels. The tanks used in a compressed air motor have a longer lifespan in comparison with pumps, which after a while suffer from a reduction in performance.

Fig -1: Air Tank

2. Solenoid Valve

A solenoid valve is used to periodically control the supply of air to the two port of the pneumatic piston as according to the predefined time the valve close and opens electrically and without any interruptions.

Fig -2: Solenoid Valve

3. Air compressor

An air compressor is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When tank pressure reaches its upper limit the air compressor shuts off. The compressed air, then, is held in the tank until called into use.

Fig -3: Air Compressor

4. Slider-crank mechanism

A crank is an arm attached at a right angle to a rotating shaft by which reciprocating motion is imparted to or received from the shaft. It is used to convert circular motion into reciprocating motion, or vice versa. The arm may be a bent portion of the shaft, or a separate arm or disk attached to it. Attached to the end of the crank by a pivot is a rod, usually called a connecting rod (conrod). The end of the rod attached to the crank moves in a circular motion, while the other end is usually constrained to move in a linear sliding motion.

Fig -4: Crank Piston with Chain and Rear Wheel

5. Steering System

The steering system is to achieve angular motion of the front wheels to negotiate a turn. This is done through linkage and steering gear which convert the rotary motion of the steering wheel into angular motion of the front road wheels.

6. Pneumatic piston

Pneumatic cylinder(s) (sometimes known as air cylinders) are mechanical devices which use the power of compressed gas to produce a force in a reciprocating linear motion. Like hydraulic cylinders something forces a piston to move in the desired direction. The piston is a disc or cylinder, and the piston rod transfers the force it develops to the object to be moved. Engineers sometimes prefer to use pneumatics because they are quieter, cleaner, and do not require large amounts of space for fluid storage. Because the operating fluid is a gas, leakage from a pneumatic cylinder will not drip out and contaminate the surroundings, making pneumatics more desirable where cleanliness is a requirement.

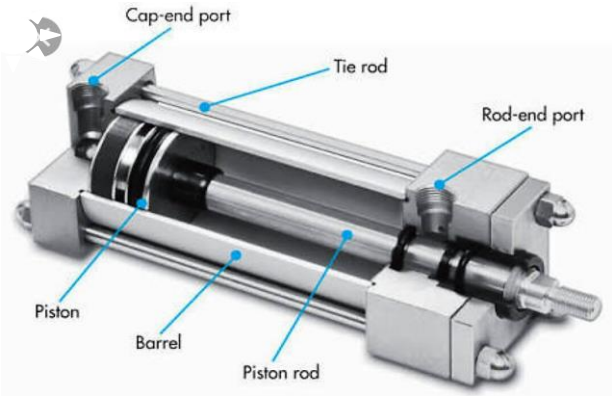

Fig -5: Pneumatic Piston

7. Electric Motor

An electric motor is an electrical machine that converts electrical energy into mechanical energy. The reverse of this is the conversion of mechanical energy into electrical energy and is done by an electric generator, which has much in common with a motor. Most electric motors operate through the interaction between an electric motor's magnetic field and winding currents to generate force. In certain applications, such as in regenerative braking with traction motors in the transportation industry, electric motors can also be used in reverse as generators to convert mechanical energy into electric power. Electric motors are used to produce linear or rotary force (torque), and should be distinguished from devices such as magnetic solenoids and loudspeakers that convert electricity into motion but do not generate usable mechanical powers, which are respectively referred to as actuators and transducers.

8. Battery

An electric battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices. . Here for the motivation of prime mover the chemical reaction takes place from which an energizing current is evolved which is responsible for the working. The working medium is sulphuric acid which is separated into columns of H ions and negative SO4 ions when mixed with water. If the poles of the cell are connected by a load, the flow of the electrons is from negative to positive.

9. Solar cells

A solar cell, or photovoltaic cell (previously termed "solar battery", is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels.

Solar cells are described as being photovoltaic, irrespective of whether the source is sunlight or an artificial light. They are used as a photo detector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity. The operation of a photovoltaic (PV) cell requires three basic attributes:

- The absorption of light, generating either electron-hole pairs or exactions.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

10. Chassis

A chassis consists of an internal vehicle frame that supports an artificial object in its construction and use, can also provide protection for some internal parts. Which is made up of carbon steel. The parts above mentioned are assembled to the chassis.

IV. Fabrication and Assembled Overview

The fabrication of CAHV consists of mainly 5 processes they are

1-Frame Preparation

The Frame is made up of M.S. along with some additional light weight components. The frame is designed to sustain the weight of the person driving the unit, the weight of load to be conveyed and also to hold the accessories like motor.

Also it should be design to bear and overcome the stresses which may arise able to due to different driving and braking torques and impact loading across the obstacles. It is drilled and tapped enough to hold the support plates. The Platform is designed with robust base so that it can hold the load along with the weight of the driving person uniformly. It is fabricated from Mild Steel at a specific angle in cross section and welded with a sheet of metal of specific thickness. The platform's alignment is kept horizontal irrespective whether it is loaded or unloaded and this is directly bolted and welded to the frame.

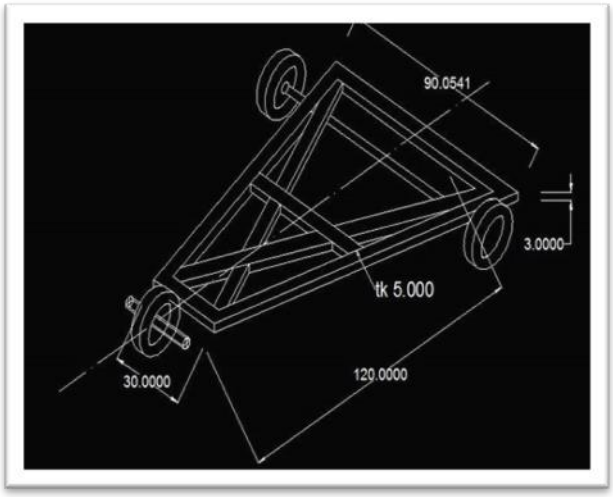

Fig -6: Layout of chassis designed using CAD software.

2-Installation of wheels and Steering Mechanism

One front wheel and two back wheels are installed. Here the steering arrangement is turn the front wheels using a hand operated steering wheel which is positioned in front of the driver, via the steering column. It connected by a universal joint to allow it to deviate somewhat from a straight line.

3-Installation of Motor and Pneumatic system

Motor and Pneumatic system are installed for powering the CAHV. The pneumatic system consists of pneumatic cylinder, Air tank, Air compressor, slider crank mechanism, chain drive system. The compressed air from the air-compressor is stored into the air tank which is delivered to the pneumatic cylinder then to the chain drive system then to the wheels. The electric motor delivers the power.

4-Mounting of Solar panel in CAHV

A solar array of a PV system can be mounted on top of the vehicle frame, generally with a few inches gap and parallel to the surface of the frame. The Frame is horizontal so the array is mounted with each panel aligned at an angle. The panels are planned to be mounted before the construction of frame, The frame can be designed accordingly by installing support brackets for the panels before the frame can be installed.

5-Connecting of pneumatic hoses and electrical wire appropriately

Motor and Pneumatic system are installed for powering the CAHV. It is necessary to connect high pressure tank to that of the solenoid valve, and the wiring is done with proper joints.

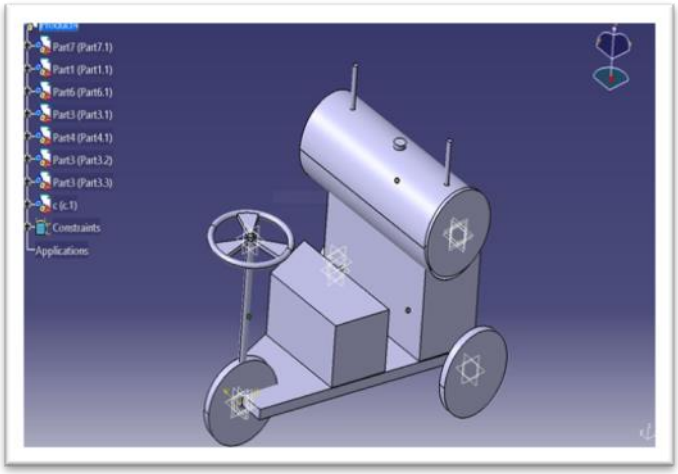

Fig -7: Assembled view of CAHV designed using CATIA software.

6-Energy Density: General Relationships

As a form of potential energy, the energy contained in a compressed air tank is equal to the work that can be done when gas in that tank expands to ambient pressure. This relationship is described as follows, which shows tank energy as a function of its volume and pressure[6].

$$E_T=-P_TV_T\ln(P_A/P_B)\text{----(1)}$$

Where,

ET = tank energy,
VT = tank volume, and
pA, pT = ambient and tank pressures, respectively.

The energy embodied in compressed air itself can be expressed independently of the storage tank, in the form of energy density per unit volume or unit mass.

$$Ev =E_T/V_T=P_T\ln(P_T/P_A)\text{----(2)}$$

Where,

E_V, Em = energy density per unit volume and mass, respectively; mT = tank mass;
R = universal gas constant;
T = temperature of gas;and
M = molecular mass of gas.

In vehicle design, volumetric density is of prime importance, since the amount of fuel that can be stored onboard is typically limited by a vehicle's volumetric space constraints rather than its weight constraints.

As shown in Equation 2, the volumetric density is solely a function of tank and ambient pressures. Thus the only way to increase volumetric density is to increase the maximum tank pressure. However, as shown later, an increase in tank pressure leads to greater inefficiencies in the expansion process, partially negating the benefits of greater energy storage. Notably, the volumetric density does not vary with the type of gas being compressed (E_V is independent of M); air has the same volumetric energy density as that of heavier gases such as carbon dioxide (CO2) and lighter gases such as helium.

Comparison with Other Fuels:

Even at high pressures, compressed air carries much less energy than other transportation energy sources, including liquid and gaseous fuels as well as rechargeable batteries. Compressed air holds only 0.5% of the energy in gasoline and 1.5% of the energy of gaseous compressed natural gas (CNG). Similarly, the energy density of compressed air is poor compared with the types of rechargeable batteries available for vehicle use: lead acid (Pb–acid), nickel cadmium (NiCd), nickel metal hydride (NiMH), and lithium ion (Li-ion). Although batteries are significantly heavier than compressed air and hold less energy by mass, they still outperform in terms of volume, with compressed air holding 12% of the energy of Li-ion batteries.

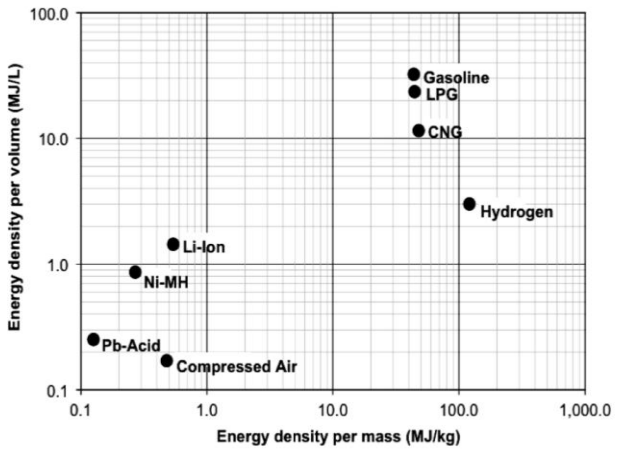

Chart -1: Energy density of compressed air and other fuels (LPG, liquid propane gas, Compressed Natural Gas)

These relationships are shown in Figure, which plots the energy densities for all fuels on a logarithmic scale. This comparison is based on reported energy densities of fuels and rechargeable batteries and assumes that compressed air and CNG are compressed to 300 bar (4,350 psi)[6].

V. Simulation:

Simulation of CAHV is done by two power systems. Electric and pneumatic system.

Such that by pneumativ system, High pressure air is introduced to the engine that pushes the piston and creates movement. The compressor will use air from around the vehicle to refill the compressed air tank. Vehicle propelled with this system will have tanks that will probably hold compressed air to about 100 psi. A valve on its tank that allows air to be released into the hoses. Where the pressure of the air's expansion will push against the piston up and down.

In case of Electrical power the Solar cells attached in the vehicle absorb the solar energy from the sun. This is then supplied to the Battery then to the Electric motor. Here for the motivation of prime mover the chemical reaction takes place from which an energizing current is evolved which is responsible for the working.

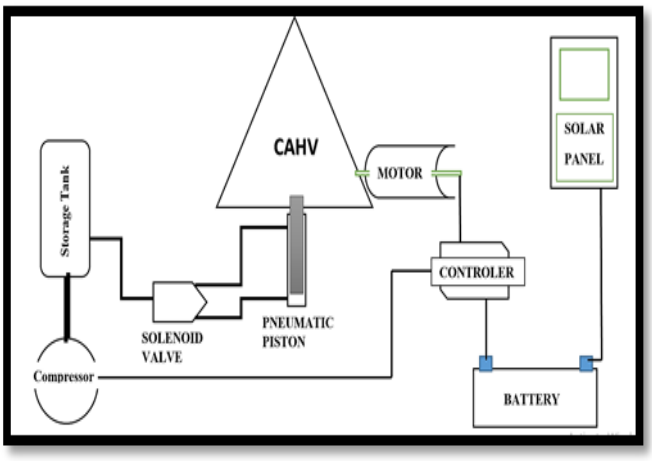

Fig -8: Flow Chart Representation on Circuit of CAHV

VI. Results and Discussion:

Compressed air vehicles are our near future and advancements in the presented project can be taken up by doing some ideal methods like:

1. Inserting an intermediate compressor after the gas exits the engine and compresses the air again to the reservoirs.

2. Making a hybrid engine comprised of multiple ways of powering up the vehicle like gasoline and compressed air; electric and compressed air; re-cyclic modules etc.

3. Making the chassis light weight by selecting proper materials can also greatly affect the efficiency of the CAV.

Fig -9: Fabricated Model Of Our CAHV

Performance Calculation with Compressed Air:

Table -1:

S.NO	TOTAL MEMBERS	TOTAL LOAD APPLIED (Kg)	SPEED (Km/hr)	PRESSURE REQUIERED (bar)
1	1	80+60 =140	15	3+1.2 =4.2
2	2	80+120 =200	13	3+2.4 =5.4
3	3	80+180 =260	12	3+3.6 =6.6

VII. Advantages:

In comparison to petrol or diesel powered vehicles "Compressed Air powered Hybrid vehicles" have following advantages:

• Air, on its own, is non-flammable, abundant, economical, transportable, and storable and, most importantly, nonpolluting.

• Compressed air technology reduces the cost of vehicle production by about 20%, because there is no need to build a cooling system, fuel tank, spark plugs or silencers.

• High torque for minimum volume.

• The mechanical design of the engine is simple and robust.

• Low manufacture and maintenance costs as well as easy maintenance.

• Lighter vehicles would mean less abuse on roads, thus resulting in longer lasting roads.

• The price of fueling air powered vehicles will be significantly cheaper than current fuels.

• Transportation of the fuel would not be required due to drawing power off the electrical grid. This presents significant cost benefits. Pollution created during fuel transportation would be eliminated.

• Compressed-air vehicles are unconstrained by the degradation problems associated with current Hydro carbon systems.

• Much like electrical vehicles &air powered vehicles would ultimately be powered through the electrical grid which makes it easier to focus on reducing pollution from one source, as opposed to the millions of vehicles on the road.

VIII. Challenges of Hybrid Vehicles:

1. Need of proper recycling methods for Lead Acid Battery.
2. A tank containing over compressed air is risky and dangerous.
3. Low boot space, as compressed air car, will be having a compressed air tank.
4. Running the vehicle on compressed air will be requiring the provision for filling the compressed air in the tank.

IX. Conclusion:

The Compressed Air Hybrid Vehicle is easy for production as well as to establish. It is suitable for running in the atmospheric air. There is no need of any petroleum products to run the vehicle. Maintenance cost is also less.

Hence this hybrid vehicle is more efficient and useful compared to the current automobiles using non-renewable fuels. So we suggest this vehicle as a better alternative to the automobiles using petroleum products for the future.

Compressed air technology allows for engine that are both non-polluting and economical. After ten years of research and development, the compressed air vehicle will be introduced worldwide. Unlike electric or hydrogen powered vehicles, compressed air vehicles are not expensive and do not have a limited driving range.

This is a revolutionary car which is not only eco- friendly, pollution free, but also very economical. This addresses both the problems of fuel crises and pollution. However excessive research is needed to completely provethe technology for both its commercial and technical viability.

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