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A Fuel Efficiency of Compressed Air Light Weight Vehicle Design in Automotive Industry

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Abstract:
The latest trend in the automotive industry is to develop light weight vehicles. Every automotive industry is looking to reduce the weight of the vehicle as it helps in the better handling of the vehicle and increases the efficiency of the vehicle. Today, the heavy vehicles are known for producing a large amount of harmful gases like CO_2, SO_2 etc. which act as the major source for global warming. So research is going on to find a light weight vehicle which does not pollute the environment. One of the alternatives is the use of compressed air to generate power to run an automobile. Due to the unique and environmental friendly properties of air, it is considered as one of the future fuels which will run the vehicles. So in this paper an effort is made to study the extent of research done and the potential advantages and disadvantages of the compressed air technology.

Keywords:
Compressed air engine (CAE), 3Way gate valve, Compressed air vehicles, Compressed air tank.

I. Introduction

compressed-air vehicle is powered by an Air Operated four wheeler, using compressed air, which is stored in a tank [1], Instead of mixing fuel with air and burning it in the engine to drive pistons with hot expanding gases, compressed air vehicles (CAV) use the expansion of compressed air to drive their pistons [2], Compressed air propulsion may also be incorporated in hybrid systems, e.g., battery electric propulsion and fuel tanks to recharge the batteries.

This kind of system is called hybrid-pneumatic electric propulsion [3].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 [3]. He constructed a four-wheeler with 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 is which works on compressed air engine (CAE).

He developed compressed air- 4- cylinders 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. Light weight vehicles are the next advancement in the development of automobiles.[3] Reducing the weight of the vehicle has many advantages as it increases the overall efficiency of the vehicle, helps in improving maneuverability, requires less energy to stop and run the vehicle. The latest researches are going on around the world in order to come up with innovative ideas.

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But global warming is also one of the problems which is affecting the man. The temperature of the earth is increasing drastically and this in turn is causing climatic changes. The fossil fuels are widely used as a source of energy in various different fields like power plants, internal & external combustion engines, as heat source in manufacturing industries, etc. But its stock is very limited and due to this tremendous use, fossil fuels are diminishing at faster rate. So, in this world of energy crisis, it is necessary to develop alternative technologies to use renewable energy sources, so that fossil fuels can be conserved. One of the major source of the pollution is the smoke coming out from the automobiles. So an alternative way of producing the running the vehicle must be made so that we can prevent further damage to the earth.

The alternative sources of energy available are solar, electric, atmospheric air etc. Air acts like a blanket for the earth. It is the mixture of gasses, which makes it neutral and non-polluting. It has the property to get compressed to a very high pressure and retain it for a long period of time. It is cheap and can be found abundantly in the atmosphere. So it can be used as an alternative fuel for the automobiles. Much research is going on in this field and scientists are trying to improve the effectiveness of this technology. It is experimentally found that the efficiency of the vehicle ranges from 72-95%. So this can be considered as one of the preferable choices to run the vehicle.

II. Literature Survey

Air Powered Engine

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 [4].

Study of Compressed Air Storage System as Clean Potential Energy for 21st Century

Dr. Bharat Raj Singh and Dr. Onkar Singh conducted an experiment in which they used a vaned 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 [5].
It consists of an air compressor which was used to produce and store 300 psi (21 bar 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 was found to vary from 72 to 97 %. The turbine had d/D ratio of 0.7 and the results obtained were are follows:

- 93% to 99% with variation of 6%, at speed of rotation 500 rpm for injection pressure 20 psi to 100 psi.
- 81.8% to 89.8% with variation of 8%, at the speed of rotation 1000 rpm for injection pressure 20 psi to 100 psi.
- 70.8% to 84.3% with variation of 13.5%, at the speed of rotation 1500 rpm for injection pressure 20 psi to 100 psi.
- 64.4% to 79.8% with variation of 15.4%, at the speed of rotation 2000 rpm for injection pressure 20 psi to 100 psi. 59.5% to 76.5% with variation of 17%, at the speed of rotation 2500 rpm for injection pressure 20 psi to 100 psi.
- 56.2% to 72.9% with variation of 16.7%, at the speed of rotation 3000 rpm for injection
- pressure 20 psi to 100 psi.

Vehicle Operating On Compressed Air by Inversion of Slider Crank Mechanism

A.A.Keste et al. worked on the concept of inversed slider crank mechanism to utilize the compressed air to run a vehicle [20]. In this experiment a double acting pneumatic cylinder was used in which the piston attached to a pinion which generated rotation motion.

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III. Working Principle

The main components involved in this project consist of engine, battery, compressor unit, spur gear arrangement and linkages. All components are mounted on the frame called base frame. Here compressor unit is placed at the rear side of the vehicle. 12 Volt DC compressors are used to compress the air. That compressed air is send directly to the engine inlet. Due to that, engine will function. The engine output shaft is connected with chain drive that tends to rotate the rear wheel. So that vehicle will move forward. Here dynamo is connected to the rear shaft of the vehicle by using spur gear arrangement to generate the electrical power. That power is stored in battery. At front side of the vehicle, linkages are provided for steering purpose.

IV. HARDWARE COMPONENTS

4.1 Chain Drive

Mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles. It is also used in a wide variety of machines besides vehicles. The power is conveyed by a roller chain, known as the drive chain represented in figure 1, passing over a sprocket gear, with the teeth of the gear meshing with the holes in the links of the chain. The gear is turned, and this pulls the chain putting mechanical force [4].

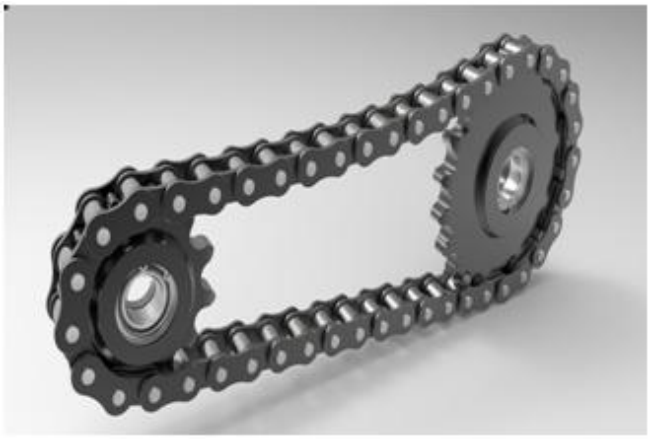

Fig1: Chain Drive

4.2 Engine

A four-stroke engine is an internal combustion engine in which the piston completes four separate strokes while turning a crankshaft.[2] A stroke refers to the full travel of the piston along the cylinder, in either direction. The four separate strokes are termed:

- Intake: This stroke of the piston begins at top dead center (T.D.C.) and ends at bottom dead center (B.D.C.). In this stroke the intake valve must be in the open position while the piston pulls an air-fuel mixture into the cylinder by producing vacuum pressure into the cylinder through its downward motion.
- Compression: This stroke begins at B.D.C, or just at the end of the suction stroke, and ends at T.D.C. In this stroke the piston compresses the air-fuel mixture in preparation for ignition during the power stroke (below). Both the intake and exhaust valves are closed during this stage.
- Power: This is the start of the second revolution of the four stroke cycle. At this point the crankshaft has completed a full 360 degree revolution. While the piston is at T.D.C. (the end of the compression stroke) the compressed air-fuel mixture is ignited by a spark plug (in a gasoline engine) or by heat generated by high compression (diesel engines), forcefully returning the piston to B.D.C. This stroke produces mechanical work from the engine to turn the crankshaft.
- Exhaust: During the exhaust stroke, the piston once again returns from B.D.C. to T.D.C. while the exhaust valve is open. This action expels the spent air-fuel mixture through the exhaust valve.

The problem with compressed charge engines is that the temperature rise of the compressed charge can cause pre-ignition. If this occurs at the wrong time and is too energetic, it can damage the engine. Different fractions of petroleum have widely varying flash points (the temperatures at which the fuel may self-ignite). This must be taken into account in engine and fuel design. The tendency for the compressed fuel mixture to ignite early is limited by the chemical composition of the fuel.

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There are several grades of fuel to accommodate differing performance levels of engines. The fuel is altered to change its self-ignition temperature. There are several ways to do this. As engines are designed with higher compression ratios the result is that pre-ignition is much more likely to occur since the fuel mixture is compressed to a higher temperature prior to deliberate ignition. The higher temperature more effectively evaporates fuels such as gasoline, which increases the efficiency of the compression engine. Higher Compression ratios also mean that the distance that the piston can push to produce power is greater (which is called the Expansion ratio).

The octane rating of a given fuel is a measure of the fuel's resistance to self-ignition. A fuel with a higher numerical octane rating allows for a higher compression ratio, which extracts more energy from the fuel and more effectively converts that energy into useful work while at the same time preventing engine damage from pre-ignition. High Octane fuel is also more expensive. Diesel engines by their nature do not have concerns with pre-ignition.They have a concern with whether or not combustion can be started. The description of how likely Diesel fuel is to ignite is called the Cetane rating. Because Diesel fuels are of low volatility, they can be very hard to start when cold. Various techniques are used to start a cold Diesel engine, the most common being the use of a glow plug.

The maximum amount of power generated by an engine is determined by the maximum amount of air ingested. The amount of power generated by a piston engine is related to its size (cylinder volume), whether it is a two-stroke or four-stroke design, volumetric efficiency, losses, air-to-fuel ratio, the calorific value of the fuel, oxygen content of the air and speed (RPM). The speed is ultimately limited by material strength and lubrication. Valves, pistons and connecting rods suffer severe acceleration forces. At high engine speed, physical breakage and piston ring flutter can occur, resulting in power loss or even engine destruction.

Piston ring flutter occurs when the rings oscillate vertically within the piston grooves they reside in. Ring flutter compromises the seal between the ring and the cylinder wall, which causes a loss of cylinder pressure and power. If an engine spins too quickly, valve springs cannot act quickly enough to close the valves. This is commonly referred to as 'valve float', and it can result in piston to valve contact, severely damaging the engine. At high speeds the lubrication of piston cylinder wall interface tends to break down. This limits the piston speed for industrial engines to about 10 m/s.

4.3 Gate Valve

Gate valve, also known as a sluice valve, is a valve that opens by lifting a round or rectangular gate/wedge out of the path of the fluid. The distinct feature of a gate valve is the sealing surfaces between the gate and seats are planar, so gate valves are often used when a straight-line flow of fluid and minimum restriction is desired. The gate faces can form a wedge shape or they can be parallel. Gate valves are primarily used to permit or prevent the flow of liquids, but typical gate valves shouldn't be used for regulating flow, unless they are specifically designed for that purpose and represented in figure2. Because of their ability to cut through liquids, gate valves are often used in the petroleum industry. For extremely thick fluids, a specialty valve often known as a knife valve is used to cut through the liquid.

Fig2: 3way Gate valve

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On opening the gate valve, the flow path is enlarged in a highly nonlinear manner with respect to percent of opening. This means that flow rate does not change evenly with stem travel. Also, a partially open gate disk tends to vibrate from the fluid flow. Most of the flow change occurs near shutoff with a relatively high fluid velocity causing disk and seat wear and eventual leakage if used to regulate flow. Typical gate valves are designed to be fully opened or closed. When fully open, the typical gate valve has no obstruction in the flow path, resulting in very low friction loss. Gate valves are characterized as having either a rising or a non-rising stem. Rising stems provide a visual indication of valve position because the stem is attached to the gate such that the gate and stem rise and lower together as the valve is operated.

4.4 Air Tank

Storage can be used to control demand events (peak demand periods) in a compressed air system by reducing both the amount of pressure drop and the rate of decay. Storage can be used to protect critical pressure applications from other events in the system. Storage can also be used to control the rate of pressure drop in demand while supporting the speed of transmission response from supply. For some systems, it is important to provide a form of refill control such as a flow control valve. Many systems have a compressor operating in modulation to support demand events, and sometimes strategic storage solutions can allow for this compressor to be turned off.

Air tank is a container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. The pressure differential is dangerous, and fatal accidents have occurred in the history of pressure vessel development and operation. Consequently, pressure vessel design, manufacture, and operation are regulated by engineering authorities backed by legislation. For these reasons, the definition of a pressure vessel varies from country to country, but involves parameters such as maximum safe operating pressure and temperature, and are engineered with a safety factor, corrosion allowance, minimum design temperature (for brittle fracture), and involve nondestructive testing, such as ultrasonic testing, radiography, and pressure tests, usually involving water, also known as a hydro test, but could be pneumatically tested involving air or another gas. The preferred test is hydrostatic testing because it's a much safer method of testing as it releases much less energy if fracture were to occur (water does not rapidly increase its volume while rapid depressurization occurs, unlike gases like air, i.e. gasses fail explosively). In the United States, as with many other countries, it is the law that vessels over a certain size and pressure be built to Code, these vessels also require an Authorized Inspector to sign off on every new vessel constructed and each vessel has a nameplate with pertinent information about the vessel such as maximum allowable working pressure, maximum temperature, minimum design metal temperature.

4.5 Air Tank Safety Measures

(a) Each air tank shall be protected by 1 or more safety valves and other indicating and controlling devices that will insure safe operation of the tank.[5] If the tank has a volumetric capacity in excess of 2,000 gallons, it shall be fitted with at least 2 safety valves, the smallest of which shall have a relieving capacity of at least 50 percent of the relieving capacity of the largest valve.

(b) Safety relief valves shall:

- Be constructed and installed in accordance with ASME Boiler and Pressure Vessel Code,
- Be located and installed so that they cannot be readily rendered inoperative.
- No valve of any description shall be placed between the required safety valve or rupture disc and the air tank.
- The opening or connection between the tank and safety valve or valves shall have a cross-sectional area at least equal to the combined areas of all attached safety valve inlets.

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- Be of the direct spring-loaded type. The springs shall not be adjusted to carry more than: 10 percent greater pressure than the set pressure stamped on the valve up to and including 250 psig; or 5 percent greater pressure than the set pressure stamped on the valve above 250 psig.
- For pressures of 2000 psig or less safety valves shall be equipped with a substantial lifting device so that the disc can be easily lifted from its seat not less than 1/8 the diameter of the seat when the pressure in the tank is 75 percent of that at which the safety valve is set to open.
- For pressures exceeding 2000 psig: the lifting device may be omitted providing the valve is removed for testing at least once each year and a record kept of this test and made available to the qualified inspector;
- Be set to open at not more than the allowable working pressure of the tank.
- Have a relieving capacity sufficient to prevent a rise of pressure in the tank of more than 10 percent above the allowable working pressure when all connected compressors are operating with all unloading devices rendered inoperative.
- Not have seats or discs of cast iron.
- Be tested frequently and at regular intervals to determine whether they are in good operating condition.

Discharge pipes from safety valves and rupture discs installed on air tanks shall:

- Have a cross-sectional area at least equal to the combined outlet areas of all valves discharging into them.
- Be designed and installed so that there will be no interference with the proper operation or discharge capacity of the safety valve or rupture disc.
- Have no valve of any description.
- Be fitted with open drains which will prevent the accumulation of liquid above the safety valve or rupture disc.
- Be installed and supported in a manner that will prevent undue stresses on the safety valve or rupture disc.
- Be led to a safe place of discharge.
- Each air tank shall be equipped with a suitable pressure indicating gage with the dial graduated to approximately double the operating pressure, but in no case less than 1.2 times the pressure at which the safety-relieving device is set to function.

Each air tank shall be equipped with a manually operated, valved drain located at the lowest point where water can collect. The valve for this drain shall be suitably located for convenient operation. Automatic drains shall not be considered as complying with this order unless also equipped with a manually operated by-pass.

4.6 Air Compressor

Compressor is the air producing machine. They collect the airs from the atmosphere are in the running of machine are engine [7]. Air compressors are utilized to raise the pressure of a volume of air. Air compressors are available in many configurations and will operate over a very wide range of flow rates and pressures. Compressed air was expelled by primitive man to give glowing embers sufficient oxygen to allow them to flare up into a fire and it shows in figure 3. During the compression process, the temperature increases as the pressure increases. This is known as polytypic compression. The amount of compression power also increases as the temperature increases. Compressors are staged thereby reducing the temperature rise and improving the compression efficiency. The temperature of the air leaving each stage is cooled prior to entering the next stage. This cooling process is called inter cooling. Volumetric efficiency also increases with multi-stage compression since the pressure ratio over the first stage will be decreased. Selection of the air compressor is only the first step in designing an efficient and reliable compressed air system.

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The air exiting the compressor is saturated with moisture and will have compressor lubricants (lubricated compressors only). Other chemicals that may have been drawn into the compressor intake may also be present [8]. This contamination is harmful to many processes, pneumatic tools, instruments and equipment. Air purification equipment, filters, air dryers, breathing air purifiers, monitoring equipment, used alone or in combination will remove these contaminants. Selection and purchase of the compressor and necessary purification equipment can be easily done on the Compressed air site. Our application engineers are ready to answer all of your questions and to assist you in placing your order. And it work in the process of rotating the fan and the piston movement with the help of current supply.

Fig3: Compressed air tank

4.7 Battery

The battery is the primary source of electrical energy in most of the vehicles. It stores chemicals, not electricity. Two different type of lead in an acid mixture reacts to produce electrical pressure. This electro chemical reaction changes chemical energy into electrical energy.

V. Result and Discussion

Compressed air technology allows engines that are both nonpolluting and economical. With the use of non-conventional energy sources such as compressed air engine we can set a milestone in the field of green technology because it is the demand of the time to adopt green technology. The below figure 4, figure 5 and figure 6 are represents the experimental results.

5.1 Experimental results

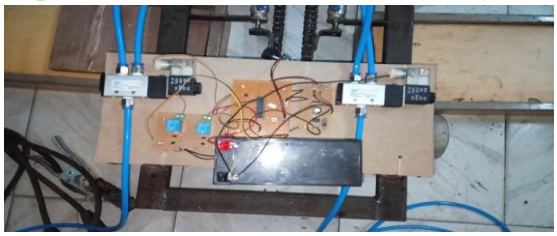

Fig4: Electronic circuit connections

Fig5: Chain arrangement

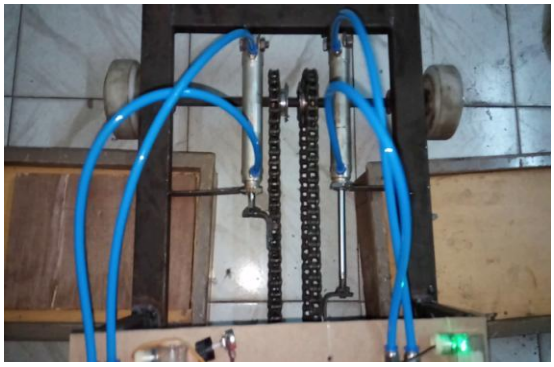

Fig6: Chain arrangement with Pneumatics

5.2 Advantages of compressed air powered vehicle

In comparison to petrol or diesel powered vehicles "air powered 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.

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- 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.
- When the air is being compressed at reasonable speeds, it heats up. The heat given off during compression could be reclaimed for space heating or water heating, or used in a sterling engine.
- 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 comparable in many ways even to electric vehicles and their potential advantages over electric vehicles include:
- Compressed-air vehicles are unconstrained by the degradation problems associated with current battery 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.
- Compressed-air tanks can be disposed of or recycled with less pollution than batteries.
- The tank may be able to be refilled more often and in less time than batteries can be recharged, with refueling rates comparable to liquid fuels.
- 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.

VI. Conclusion

It's important to remember that while vehicles running on only compressed air might seem like a distant dream, but they still have public interest due to their environmental friendly nature. Compressed air for vehicle propulsion is already being explored and now air powered vehicles are being developed as a more fuel-efficient means of transportation. This paper 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 refueling as compared to battery operated vehicle.

On the whole, the technology is just about modifying the engine of any regular IC engine vehicle into an Air Powered Engine. The Air Powered Engine technology is cheaper in cost and maintenance, can be easily adapted by the masses and it doesn't cause any kind of harm to the environment. Instead, it's wide spread use will help mankind in controlling the serious problem of global warming.

At the end of this review we conclude that the compressed air technology can be tested and developed using the Vaned Type Novel Air Turbine as there are minimal losses and practically their efficiency varies from 72-97% which is very high when compared to a conventional IC engine. Future developments can be made by designing an ideal vehicle for this kind of engine.

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