Development in Research Work of Compressed Air Powered Engine by Increasing Its Air Efficiency

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Abstract— Light utility vehicles are becoming very popular means of independent transportation for short distances. Cost and pollution with petrol and diesel are leading vehicle manufacturers to develop vehicles fuelled with alternative energies. Engineers are directing their efforts to make use of air as an energy source to run the light utility vehicles. This paper is a report on "How to increase efficiency of air in air powered engines". However, this engine has zero emission, by increasing its efficiency it will cover more distance in less amount of air.

Key words: Compressed Air Engine, Pollution Control, No Heat Generation, Air Car

I. INTRODUCTION

One cannot accurately claim that compressed air in energy and locomotive sector is recent technology. Two centuries before Dennis Pippin apparently came up with the idea of using compressed air (Royal Society London, 1687). In 1872 the Mekarski air engine was used for steer transmit, consisting of a single stage engine. Numerous locomotives were manufactured and a number of regular lines were opened up (the first in Nantes in 1879). In 1892, Robert Hardie introduced a new method of heating that at the same time served to increase the range of the engine.

Currently two types of technologies exist in compressed air engines technology

- Single energy compressed air engine.
- Dual energy compressed air plus fuel engines.

In single energy engine only one energy is used i.e. only compressed air is used. In this technology the advantages are that there is zero emission and as only compressed air is used efficiency is more. But at the same time, it has some drawbacks too like the torque is very less in compressed air engine, the maximum speed that a compressed air car can run is 50 kmph.

In Dual energy engines two types of energies are used i.e. one energy used is compressed air and another energy can be gasoline or electricity. The duel energy engine overcame a drawback of single energy engine, the duel energy engine first runs on compressed air till 50 kmph, but after 50 kmph the second source of energy is used for higher speed. [1]

II. COMPRESSED AIR TECHNOLOGY

Mankind has been making use of uncompressed air power from centuries in different application viz., windmills, sailing balloon car, hot air balloon flying and hang gliding etc. The use compressed air for storing energy is a method that is not only efficient and clean, but also economical and has been used since the 19th century to power mine locomotives, and was previously the basis of navel torpedo propulsion. 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 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 run. The air compressors are built into them. The principle of compressed-air propulsion is to pressurize the storage tank and then connect it to something very like a reciprocating stream engine of the vehicle. Instead of mixing fuel with air and burning it in the engine to drive their pistons with hot expanding gases, compressed air vehicles (CAV) use the expansion of compressed air to drive their pistons. Thus, making the technology free from difficulties, both technical and medical, of using ammonia, petrol, or carbon disulphide as the working fluid. Manufacturers claim to have designed engine that is 90 percent efficient. The air is compressed at pressure about 150 times the rate the air is pressurized into car tyres or bicycle. The tanks must be designed to safety standards appropriate for a pressure vessel. The storage tank may be made of steel, aluminium, carbon fibre, Kevlar or other materials or combinations of the above. The fibre materials are considerably lighter than metals but generally more expensive. Metal tanks can withstand a large number of pressure cycles, but must be checked for corrosion periodically. A company has stated to store air in tanks at

4,500 pounds per square inch (about 30 Mpa) and hold nearly 3,200 cubic feet (around 90 cubic meters) of air. The tanks may be refilled at a service station equipped with heat exchangers, or in a few hours at home or in parking lots, plugging the vehicle into an on-board compressor. The cost of driving such a car is typically projected to be around Rs. 60 per 100km, with a complete refill at the "tank-station" at about Rs. 120 only. [1] [2] [3]

III. HOW COMPRESSED AIR RUNS A CAR

The laws of physics dictate that uncontained gasses will fill any given space. The easiest way to see this 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 surfaces, 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 run.

The air cars will have air compressors built into them. After a brisk drive, you'll be able to 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 rather slow method to refuelling and will probably take up to two hours for a complete refill. If the idea of an air car catches on, air refuelling 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.

The first air car will almost certainly use the Compressed Air Engine (CAE) developed by the French company, Motor Development International (MDI). Air cars using the engine will have tanks that will probably hold about 3,200 cubic feet (90.6 kilolitres) of compressed air. The vehicle's accelerator operates a valve on its tank that allows air to be released into a pipe and then into the engine, where the pressure of the air's expansion will push against the pistons and turn the crankshaft. This will produce enough power for speeds of about 35 miles (56 kilometres) per hour. When the air car surpasses the speed, a motor will kick in to operate the in-car air compressor so it can compress more air on the fly and provide extra power to the engine. The air is also heated as it hits the engine, increasing its volume to allow the car to move faster. [3] [5]

IV. WORKING OF COMPRESSED AIR ENGINE

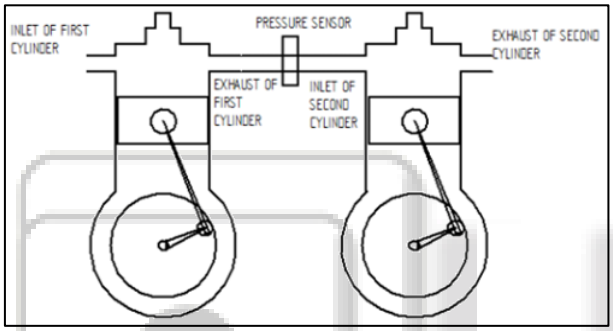

Fig. 1: Modified Compressed Air Engine

The working of the Compressed Air Engine (CAE) is similar to the working of the Internal Combustion Engine. The air is introduced to the engine cylinder by the inlet valve from the compressed air tank. Due to the pressure of the air the piston starts to move from Top Dead Centre (TDC) to Bottom Dead Centre(BDC) which makes the crankshaft to rotate. After the piston reaches BDC it returns to the TDC and the cycle continues.

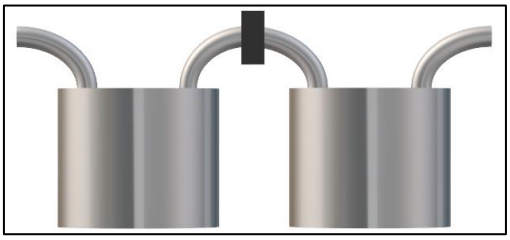

Fig. 2: 3D Diagram of Modified Compressed Air Engine

The Compressed Air Engine (CAE) can be made of 2-stroke engine as well as 4-stroke engine depending on the requirement. If more power is required 4-stroke engine is preferred but if more efficiency is required 2-stroke engine is used. As our topic is about increasing the efficiency of CAE we will be considering 2-stroke engine. The constructional features of 2-stroke engine are similar to the construction of 4-stroke engine only difference is the number of strokes. The first stroke is the expansion stroke where the inlet valve will be open and the exhaust valve will be closed and the piston will be moving from TDC to BDC. When the piston moves from BDC to TDC the compressed air is sent out from the cylinder one to cylinder two by passing through pressure sensors.

The main concept of efficiency of compressed air comes here, where the compressed air from cylinder one's exhaust valve is sent to cylinder two's inlet valve by passing through the pressure sensors instead of sending it out to the atmosphere. When the compressed air leaves cylinder one the pressure of the compressed air will not remain same as the initial pressure, the pressure will decrease. Which is not enough to push the cylinder from TDC to BDC, therefore pressure sensors are used to measure the pressure of the compressed air. Once the air enters the cylinder two through the inlet valve there will be a compressed air injector mounted at the top of the engine which will provide the required amount of the air pressure which the compressed air is lacking and the cycle takes place. Through this method the efficiency of the air would increase by 1.4 to 1.5 times (approximately). The number of cylinder that can be used for good efficiency is 2 or 3 depending on the size of the vehicle. This method cannot be applied on single cylinder engine.

V. RECENT DEVELOPMENT IN CAE & PREVIOUS RESEARCH WORK

Fig. 3: Air Pod by Tata Motors

India's Tata Motors has produced the first air car in the marketplace. Air Pod is an alternative fuel vehicle which was developed by Motor Development International, in collaboration with India's Tata Motors and Parisbased Air France. It works on the compressed air. The Air Pod's engine works with the help of two linked cylinders. Compressed air flows into the smaller cylinder first at a constant pressure of 20 bars. When the smaller piston bottoms out, the intake is closed, and the air in the small cylinder expands, flowing into the larger cylinder. Both pistons then move to exhaust the expanded air, and the cycle begins again. The 80 kg of compressed air in the Air Pod's tank has the capacity of generating 11.2 kilowatt-hours of mechanical energy when fully expanded at constant temperature. The manufacturing plant has been setup in Sardinia, Italy and it would be available in market by summer 2014.

No more working on the single cylinder four strokes engine. But here few researches are outlined as given below related to compressed air engine [2].

Air fuelled zero emission road transportation: A comparative study Haisheng Chen et al. adopted two technologies typical compressed air and liquid air power systems. Figure shows schematic diagram and working of

cycle on temperature – entropy diagram for the both systems. As per author's knowledge and belief only few works reported on this study.

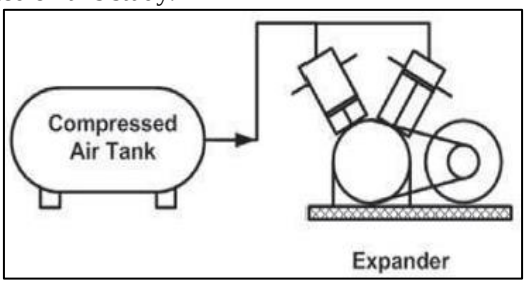

Fig 4: Compressed Air Engine

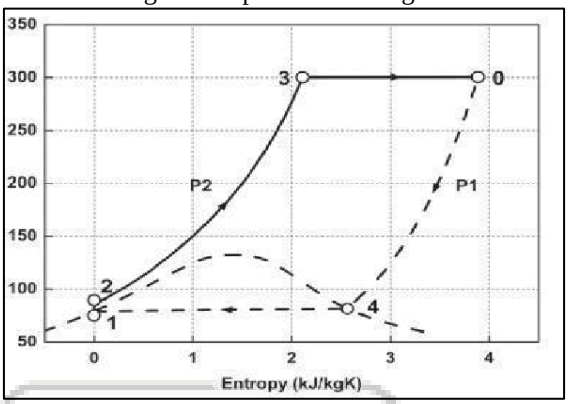

Fig. 5: T–S diagram of Engines Liquid Air Engine

Following conditions are used in the analyses Ambient pressure: P1 = 1.013 bar.

Working pressure: P2 = 300 bar. Ambient temperature: T0 = 300 K. Volume of tank: V = 300 lit. The reasons to consider a fuel tank with 300 lit Volume and 300 bar working pressure include:

(I) 300 l and 300 bars are technically feasible (ii) a High pressure and a large volume are essential to give sufficient work output for an acceptable travel Distance and (iii) compressed air vehicles with a 300-lit fuel tank within initial pressure of 300 bar have been demonstrated practically. They have concluded in their paper is two types of air fuelled engines for zero emission road transportation are compared in terms of their shaft work, coolth, efficiency and energy density. It was found that the shaft work output and the coolth of both the fuels increase with increasing working pressure or temperature. Given the working pressure and temperature, liquid air powered engines have a slightly lower specific work outputs than compressed air powered engines. At P = 300 bar and T = 300 K, the practical network outputs of the compressed air engine for isothermal ties of γ= 0.75 and 0.90 are respectively 222.8 kJ/kg and 284.2 kJ/kg, whereas the corresponding values for the liquid air engines are 184.1 kJ/kg and 245.6 kJ/kg. The volumetric energy density of liquid air fuel, however, is about 2.45 times that of compressed air fuel, and liquid air engines produce much more coolth than compressed air engines. On the other hand, the efficiency of compressed air powered engine is higher than that of liquid air powered engines, mainly because of its high energy consumption of liquefaction plants. Their analyses also suggested that an effective use of coolth is a key to improve the overall efficiency of liquid air powered engines. A novel compression strategy for air hybrid engines Amir Fazeli et al, have proposed utilizing of two storage tanks which increases the efficiency of regenerative braking of air hybrid vehicles significantly by increasing the stored air mass and, consequently, the storing pressure in the tank. Air hybrid engines have different operational modes. Illustrates the energy flow at different operational mode.

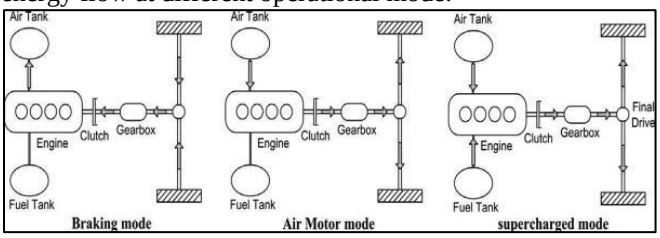

Fig. 4: Energy Flow at Different Operational Mode

The theoretical and experimental results showed the advantage of the proposed strategy over the conventional single-storage system. The proposed compression algorithm can be utilized in an air hybrid vehicle to increase the efficiency of energy recovery by the compression braking system. Compared to the double-stage regenerative braking, the double-tank system doubles the air flow rate because only one cylinder is needed to implement the proposed concept and thus, all the cylinders can be connected directly to the main tank. The proposed compression algorithm can be applied not only in air hybrid vehicle compression braking system, but also in any other applications, where higher pressure with higher air mass flow rate is demanded such as typical reciprocating compressors [1].

VI. ADVANTAGES OF CAE

In comparison to petrol or diesel-powered vehicles "air powered vehicles" have following advantages:

- Air, on its own, is non-flammable, abundant, economical, transportable, storable and, most importantly, non-polluting.
- 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 fuelling 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 Stirling 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 refuelling 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 [2].

VII. CONCLUSION

The air car which is the result of a long research and development is clean, easy to drive, high performance car. The end product is a light weight vehicle, a product that does not pollute like twentieth century vehicles and does not take a lifetime to pay off. Essentially MDI has developed a modern, clean and cheap car that meets most people's need.

Nowadays continue need of energy is increases, but basically conventional source of energy is limited due to that rate on price of petroleum is also continues hiked day by day. To satisfy their need alternate fuel or energy is required. But while considering alternate fuel some of factors are to be considered like availability, economy, and environment friendly etc., based on that CAT (Compressed Air Technology) is best technology which tend engine to zero pollutions. If further improvement is carried out with stress analysis, thermodynamic analysis, minimize compressed energy loss and other losses then efficiency of CAE may be further increases. [1][2][4][6]

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