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Recent Developments of A Compressed Air Technology in the Vehicles -A Review

Vijaykumar G Tile[1], Aditi S Bharadwaj[2], Gunasheela H S[3], Bhavana J[4]
[1]assistant Professor,Dept Of Mechanical ,Malnad College Of Engineering,Hassan.
Students Of Dept Of Mechanical, Malnad College Of Engineering,Hassan.

Abstract:- **In the present energy scenario the fossil fuelsources are fast depleting and their combustionproducts are causing global environmental problems. So it is inevitable to shift towards the use ofrenewable energy resources which in turn will reducepollution and saves fossil fuels. Air Powered Engine is an alternativetechnology which uses compressed air to run theengine and thus eliminates the use of fossil fuels.. As weare going to convert the already existing conventional engine into an air powered one, this new technology is easy to adapt. Another benefit is that it uses air as fuel which is available abundantly in atmosphere. Apart from above other technical and economic benefits are as follows: As the world is hard pressed with the energy and fuel crises, compounded by pollution of all kinds, any technologies that bring out the solutions to this problem is considered as a bounty. In one of such new technologies, is the development of a new engine called as compressed air engine which does not require any of the known fuels like diesel, petrol, CNG, LPG, hydrogen etc. this works using only compressed air.**

1.0 INTRODUCTION:

FOSSIL fuels (i.e., petroleum, diesel, natural gasand 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 green house effect, ozone layer depletion, acid rains and pollution which are posing great danger for environment and eventually for the total life on planet. These factors are leading automobile manufactures to develop cars fuelled by alternatives energies. Hybrid cars, Fuel cell powered cars, Hydrogen fuelled cars will be soon in the market as a result of it. One possible alternative is the air powered car. Compressed air Utilization in the pneumatic application has been long proven. Air motors, pneumatic actuators and others various such pneumatic equipments are in use. Compressed air was also used in some of vehicle for boosting the initial torque. Turbo charging has become one of the popular techniques to enhance power and improve the efficiencies of the automotive engine that completely runs on compressed air. There are at two on going projects (in France, by MDIand in S. Korea)that are developing a new type of car that will run only on compressed air. Similar attempt has been made but to modify the existing engine and to test on compressed air.

1.1 Technical benefits:

- the temperature of the engine while working will be slightly less than the ambient temperature.
- Smooth working of the engine due to very less wear and tear of the components.
- there is no possibility of knocking.
- No need of cooling systems and spark plugs or complex fuel injection systems.

1.2 Economic benefits:

- No use of expensive fossil fuels as the free air is compressed and taken to use.
- For this reason people can easily shift to the new technology.
- Compressors use electricity for generating compressed air which is relatively much cheaper

- The Air Powered Engine technology is cheaper in cost and maintenance and it doesn't cause any kind of harm to the environment.Thus it surely a futuristic mode of transport... Let's move from a Black Oil Past to a Green air future

1.3 Related research:

Major studies of CAV are shown in
Table 1

Table 1 the history of CAV researches

No.	Constructor	Name	Year	Country
1	MDI	Air Pod	1991~	France
2	MDI	One Flow Air	1991~	France
3	Aoyama Gakuin Univ.[1]	Mini cab	2005	Japan
4	Aoyama Gakuin Univ.[1]	Mini cab turbo	2005	Japan
5	5th grade chase	Air car	2007	America
6	Dalhousie University	Air powered racing kart	2008	Canada
7	Students of Technical College	Air powered motorcycle	2009	India
8	Chinese senior student	Air powered bicycle	2009	China
9	Nihon Univ.	Air powered bicycle	2009	Japan
10	Air Car Factory	Cold External Combustion Engine	-	-

Table 2 the spec of CAV developed in the past

No.	Air tank pressure [MPa]	Air tank Capacity [L]	Max Power	Max Speed [km/h]	Urban range [km]
1	35.0	175	4kw	45~70	220
2	35.0	300	15cv	90	100
3[1]	14.7	47	6.9kw	32	-
4[1]	14.7	47	6.9kw	32	-
5	-	-	-	-	-
6	-	-	3.4HP	43	-
7	-	-	-	-	-
8	-	-	-	80	0.5~0.6

1.4 Concept new hybrid CAV

In order to get enough potential for a CAV as commercial vehicle, the new type of system concept of a CAV is designed by keeping its zero emission and simple characteristics as future environmental solution for automobile.

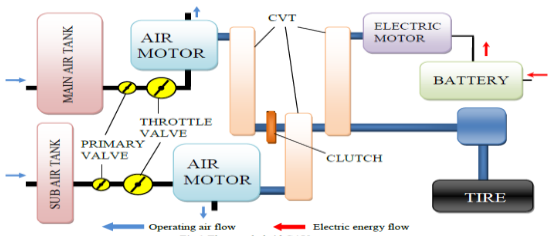


Fig.1 The new hybrid CAV system concept

The hybrid CAV concept is suggested in Figure 1 using a compressed air, electrical energy storage (Battery), and recompressed kinetic energy recovery system to provide the torque to each CVT. In order to make this system to work as a compressed air based vehicle (not an electrically based vehicle), the battery filled with energy is a half of the total energy of the main air tank.

This system is consisted of three types of drive systems:

1. Main air motor system; originally a simple compressed air vehicle system
2. Sub air motor system; a kinetic energy recovery and release system
3. Electric motor system; accelerating the vehicle of two air-motored systems to support the shortage

1.5 Numerical analysis of the CAV performance:

In order to analyze the CAV performance, the car specification is provided as shown in Table 3. The specifications of the essential number of the vehicle components are adopted from the typical Japanese light truck made by Mitsubishi motor company to use them for a simple CAV prototype made a few years ago in our laboratory

Table 3 the specification of the CAV for the numerical simulation

Basic specification	
Weight	795[kg]
Effective tire diameter	0.54[m]
Front Area	2.3157[m2]
Air motor specification	
Maker	GAST
Model	16AM-FRV-13
Max Power	6.9[kW]
Number of vanes	6
Electric motor specification	
Maker	Advanced DC
Model	140-01-4005 direct recoil motor
Battery specification	
Type	Lithium-ion
Cell layout	2 series, 160 parallel
Drive train specification	
Main air tank volume	100~800[L]
Main air tank pressure	70.0[MPa]
Sub air tank volume	100[L]
Supplying electric current for the E-motor	60[A]
Recovering pressure of sub air system	0.7[MPa]
Operating pressure of main system	0.56[MPa]
Assisting pressure of sub system	0.42[MPa]

As shown in Table 3, we choose the commercial components for each system are selected to provide more practical and reliable results comparing with the simple theoretical model. The air motor is a vane type reversible air motor made by GAST .Co in US. In this simulation, the same air motors are used for both of main and sub air-drive system. The battery is made of the Lithium-ion cells and its specification is provided by the new concept model of Hitachi that was released on automotive engineering exposition in 2009. This battery cell has 3.6V and 4.8Ah potential, and has the energy concentration of 4500W/kg. As for the electric motor, the direct recoil DC motor which is a general model for the self-made EV constructed by advanced dc motor .Co, in US is selected. Hence its operating electric current are kept as 60A constantly. When the current is 60A, the max power is 3.8HP. For the transmission, it is considered that the practical specification of CVT is covered 0.3~1.4 reduction ratio.

The running road model is chosen for the 10/15 mode of simulation, which is a general bench testing method for the commercial vehicles organized by Japan automobile manufacturers association (see Figure 2)

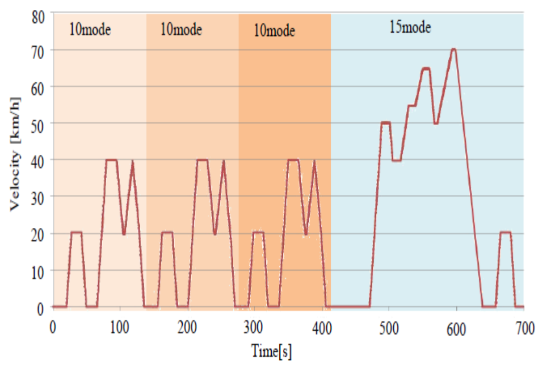


Fig.2 10/15 mode outline

In the simulation, the vehicle runs on the road, which has a repeating 10/15 mode driving strategy until its main air tank becomes empty.

1.7 NUMERICAL SIMULATION RESULTS

The dynamic performance is studied in terms of its running range and acceleration. In the acceleration point of view, the vehicle has enough accelerating performance if it runs the 10/15 running simulation mode. The simulation shows that the system of the hybrid CAV completes the 10/15 mode: its running range is related to the initial air tank volume and battery capacity. Then the main air tank volume is changed from 100 to 800L to compare each by the running ranges (see Figure 4).

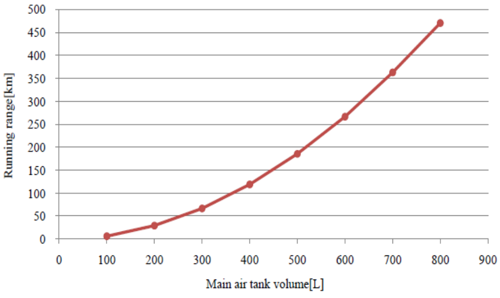


Fig.4 Relation of the main air tank volume and the running range

It is easy to predict that as the main air tank volume becomes larger, the car will be able to run longer distance. If the main tank has 800L volume, the vehicle can run 470km with the repeating 10/15 mode road models. Although 800L air tank is too big comparing with the general commercial vehicle because of the layout limitation, it provides enough distance to use every day base.

Table 4 Running range of each type of vehicles

Maker/Model(Year)	Type	Running range [km]	Fuel energy efficiency [km/MJ]
Toyota/Vitz (2009)	1496cc Gasoline Engine	781	0.607
Toyota/COROLLA(2009)	1797cc Gasoline Engine	860	0.561
Toyota/PRIUS (2009)	Split Hybrid	1597	1.158
Honda/INSIGHT (2009)	Parallel Hybrid	1200	0.979
Honda/ACCORD (2008)	2354cc Gasoline Engine	741	0.327
Nissan/TEANA (2006)	3498cc Gasoline Engine	700	0.326
Subaru/IMPREZZA (2007)	1994cc Gasoline Engine	780	0.424
Mitsubishi/iMIEV (2009)	Electric	160	2.730
Nissan/LEAF (2010)	Electric	160~	-
Honda/FCX CLARITY (2008)	Fuel cell	620	-
Hybrid CAV simulation	800L, 70.0MPa for main air tank	470	1.575

*1: multiplied the 10/15 mode fuel efficiency [km/L] and the fuel tank volume
*2: manufacturer announced spec

The range of this CAV shows little shorter than the gasoline fuelled vehicles, which have almost three times longer range than CAV. On the other hand, this value of 470km by CAV is three times longer than that of the commercial electric vehicle, such as iMIEV, made by MITSUBISHI. There will be no problem for everyday use. Next, the fuel efficiency is studied while running (see Table 4). This value is calculated by the running range divided by the energy stored (Equation 1) at the gasoline cars.

$[kmMJ]=Ru[km]/\ 43\ MJkg\ \times fuel\ tank\ volume[L]\times 0.73[kgL]$ - Eq.1

For CAV, the energy is calculated from the initial air tank and battery specification.

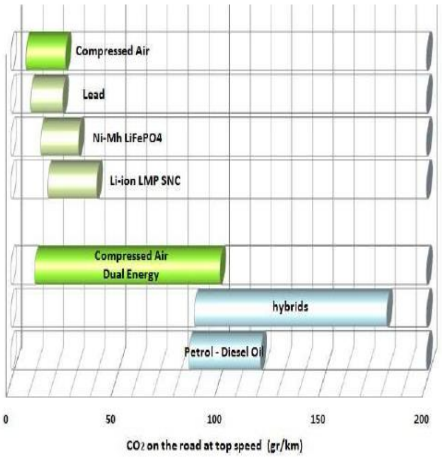
The small size and high fuel efficiency gasoline vehicles such as Toyota Vitz(named YARIS in Europe) have almost 0.6km/MJ average in the 10/15 mode simulation. For the middle size sedan, it becomes about 0.3 to 0.4km/MJ.. On the other hand, CAV has 1.575km/MJ of fuel energy efficiency in the simulation, which is higher than that of fuel combustion vehicles even though they are hybrids.

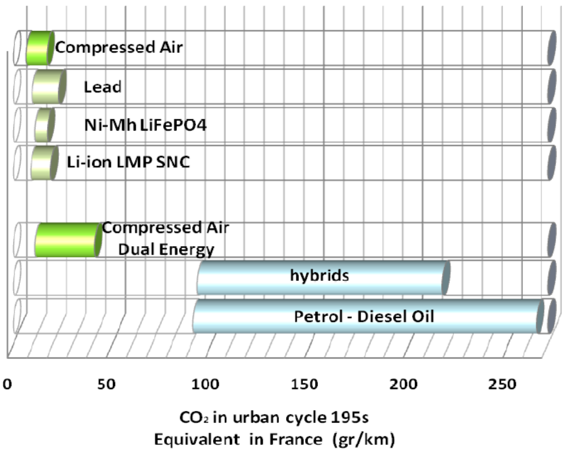
1.9Some of the vehicles are as shown:

2.0 COMPARATIVE ANALYSIS:

2.1 CO2 emissions:

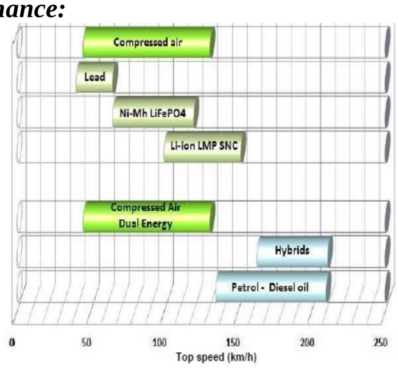
The so-called Pollution-Free vehicle which uses electricity to recharge the battery has a “CO2 to kilometre” impact directly linked to the electricity production method.. An accepted European value for the average production of electricity is indicated in a table titled “Emissions and Consumptions –CO2 (gm/km) EU Equivalent”.Nevertheless, the Air Compression process carried out by the Compressed-Air Station compressors directly driven by electricity produced by Wind Turbines or by River Micro Turbines should eventuallyeliminate the pollution caused by current electricity production methods and consequently the CO2 Emissions. For the Dual-Energy Engine vehicle the CO2 Emission result integrates the electricity production necessary to compress air for the reserve refill, and the fuel consumption at the burner to pre-heat the air before it is used up in the engine.





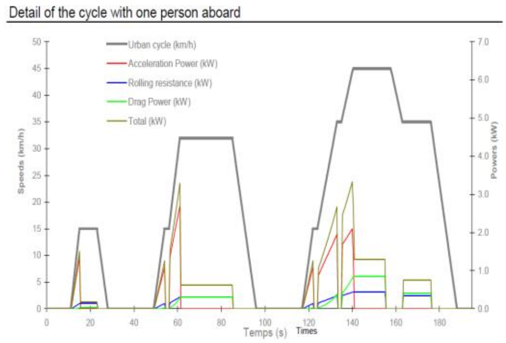
In the Dual-Energy MDI vehicles, CO2 emission at a top speed is linked to the type of vehicle. The different features (E.g.: the front surface or the mass) between a three-seats Air POD and a six-seatsAIR City Car, produce very different fuel consumption performances at top speed.

2.4 Performance:



According to the version and the technology in use, the vehicles stipulated in the Comparative Analysis are specifically for urban and suburban applications. All of the vehicles yield lower performance than the conventional fossil fuel vehicles. The curves of the Electric and Compressed-Air vehicles are veryflat and therefore both of them are perfectly suited for urban use.It is apparent from this Comparative Analysis that for a given equivalent quantity of energy loaded in each version of the airpod - compressed-air airpod against a theoretical lead-ion battery airpod, the Electric version would provide a higher autonomy performance. However, the Electric version wouldnot have the benefits of the MDI Technology, such as the ultra-fast refilling, the long lifetime of tank, and most important of all, the selling price being one third of the Electric Cars.

2.5 Vehicle characteristics table:



2.6ADVANTAGES

•It uses no gasoline or other bio-carbon based fuel.
•Refueling could be done at home using an air compressor or at service stations. It is less costly and more effective to manage carbon emissions than from individual vehicles
•Compressed air engines reduce the cost of vehicle production, because there is no need to build a cooling system, spark plugs, starter motor, or mufflers.
•The rate of self-discharge is very low opposed to batteries that deplete their charge slowly over time making them more durable than the electric cars.
•Expansion of the compressed air lowers its temperature; this may be exploited for use as air conditioning.

2.7Disadvantages

The principal disadvantage is the indirect use of energy. Energy is used to compress air, which - in turn - provides the energy to run the motor. When electrical energy is converted to compressed air, and when the compressed air is converted into mechanical energy conversion of energy between forms results in loss.

- Refuelling the compressed air container may take as long as 4 hours, though specialized equipment at service stations may fill the tanks in only 3 minutes.
- When air expands in the engine it cools dramatically and must be heated to ambient temperature using a heat exchanger. The heat exchanger can be problematic
- This leads to the necessity of completely dehydrating the compressed air. If any

humidity subsists in the compressed air, the engine will stop due to inner icing.

- The overall efficiency of a vehicle using compressed air energy storage, using the above refueling figures, is around 5-7%. For comparison, well to wheel efficiency of a conventional internal-combustion drive train is about 14%,
- Early tests have demonstrated
  the only published test of a vehicle running on compressed air alone was limited to a range of 7.22 km

2.8CRASH SAFETY

Safety claims for light weight vehicle air tanks in severe collisions have not been verified. North American crash testing has not yet been conducted, and sceptics question the ability of an ultra light vehicle assembled with adhesives to produce acceptable crash safety results. In order to reduce the weight safety systems such as the airbags , ABS , and ESC may discourage manufacturers from including them. Air cars may use low rolling resistance tires, which typically offer less grip than normal tires.

2.9What future for the air-powered car.

On the market for 10 years or so, the air-powered car is struggling to find a space among other clean car technologies. Will the arrival of the new airpod model from the company Motor Development International (MDI) change the future of this kind of vehicle? An initiative that should be welcomed at a time when technological innovations are dramatically, and permanently, changing the face of the automotive sector. The latest developments in the history of the air-powered car whereas its future on the market did appear less than certain, the launch of a new model from the company MDI has now opened up new opportunities in France and worldwide. Let's come back to the history of Motor Development International (MDI), founded in 1991 by Luxemburger Guy Nègre. For more than 10 years, the company has been trying to make a name for itself with an engine for urban vehicles that is capable of functioning on compressed air.

3.1POSSIBLE IMPROVEMENTS:

Compressed-air vehicles operate to a thermodynamic process as air cools down when expanding and heats up when being compressed. As it is not possible in practice to use a theoretically ideal process, losses occur and improvements may involve reducing these, e.g., by using large heat exchangers in order to use heat from the ambient air and at the same time provide air cooling in the passenger compartment. At the other end, the heat produced during compression can be stored in water systems, physical or chemical systems and reused later.

3.2 CONCLUSIONS:

Although the acceleration and the running range are not satisfied, our CAV concept shows some possibility to develop a car for a use of a practical vehicle such as about 470 km of running range with the 800L tank. Our CAV can run the public road as similar as the fossil fuel vehicle. Better efficiency and dynamic performance may be obtained with a deeper consideration and study with the numerical simulation model which is more realistic such as including the effect of changing the state of stored air, the heat transfer, and the more detailed loss functions. We must try a different type of system strategy as well. Our real prototype CAV is now developed to see how it can run.

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