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Experimental Analysis of Pneumatic Vehicle: A Research Paper

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***Abstract*— Present scenario of the world describes, the crisis of fuel and pollution problem, along with it, conventional sources are about to deplete in near years. So, the search on alternative fuels is on progress and in demand too. Today there are several solutions to meet demand for better economy in fuel and one of them is the concept of pneumatic-hybrids. The project focuses on a hybrid-vehicle driven by air as alternate source to fuel and a battery driven too, to reduce the dependency on conventional sources. In this, compressed air is stored in storage tank/ compressor& pneumatic motor is used for conversion of pressure to mechanical energy. This pneumatic-hybrid vehicle is not only eco-friendly, pollution free but also very economical.**

An Experimental Analysis to develop a Hybrid Pneumatic Vehicle that works on compressed air. The vehicle is powered by a compressed-air engine and can be later switched to batteries. The vehicle uses a non-renewable and pollution free fuel. A Pneumatic Vehicle is a pneumatic actuator that creates useful work by expanding compressed air. When this compressed air expands, the energy is released to do work. So this energy in compressed air can also be utilized to displace a piston.

Keywords—Fuel crisis, compressed air, battery operated, pneumatic vehicle.

I. INTRODUCTION

A. Background

The society of today relies to a great extent on different means of transportation. This massive travelling is a heavy load on nature. The cars that increase in numbers every day emit toxic emissions on the highways and the airplanes consume huge amount of fossils fuels. In recent years the awareness of the effect of pollution on the environment and climate has increased. The exhaust emissions standards are getting more and more stringent and there now exists a discussion about the introduction of a mandatory emissions standard for CO2, a green house gas that contributes to the climate change which is an issue of growing international concern. This demand for lower exhaust emission levels together with increasing fuel prices leads to the demand of combustion engines with better fuel economy, which forces engine developers to find and investigate more efficient engine management.

Today there exist several solutions to achieve exhaust emissions and better fuel economy. Some examples of such solutions are VVA (Variable Valve Actuation), EGR (Exhaust Gas Recirculation), direct injection, hybridization of vehicles, just to mention a few. In this work the emphasis has been put on vehicle hybridization.

Vehicle hybridization can be done in various ways. The maybe most known example of this is electric hybrid. The main idea with electric hybridization is to reduce the fuel consumption by taking advantage of the otherwise lost brake energy. The main disadvantage with electric hybrids is that they require an extra propulsion system and large heavy batteries with a limited life-time. This introduces extra manufacturing costs which are compensated by a higher end-product price comparable to the price of high end vehicles. However, it should be remembered that the high cost will decrease as the sales volume of hybrid vehicles increase.

One way of keeping the extra cost as low as possible and thereby increase customer attractiveness, is the introduction of Pneumatic hybrid. During deceleration of the vehicle, the engine is used as a compressor that converts the kinetic energy contained in the moving vehicle into energy in the form of compressed air which is stored in a pressure tank. The system supports stop/start functionality, which means that the engine can be shut off during a full stop and thus idle losses, can be eliminated.

Numerous research teams worldwide have demonstrated the potential of the pneumatic hybrid vehicle over last decade. Simulations made by Anderson where a regenerative efficiency as high as 55% for a dual pressure tank system for heavy duty vehicles was achieved. The fuel consumption reduction for the pneumatic hybrid city bus was in the range of 23%. In the same research team presented a vehicle model with an engine model based on experimental data. The model was tested over 10 different drive cycles and the fuel consumption varied between 8% and 58%.

All the presented features of the pneumatic hybrid contribute to lower fuel consumption with the simplicity of the system; the pneumatic hybrid can be a promising alternative to the traditional vehicles of today and a serious contender to the better known electric hybrid.

B. Objective

The objective of the project is to study the new pneumatic hybrid concept and its different modes of engine operation. The objective was to more thoroughly investigate the different parameters affecting the pneumatic hybrid engine performance and to examine the potential of reduction in fuel consumption for a pneumatic hybrid vehicle.

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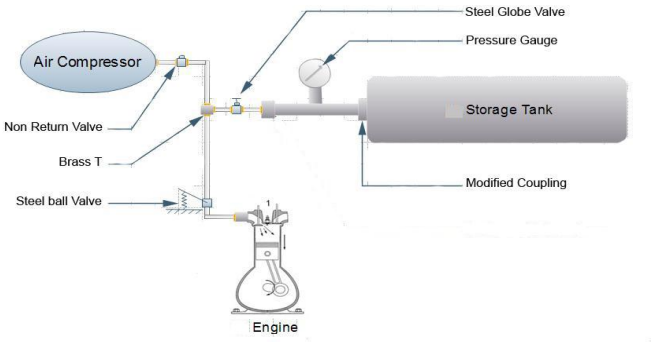

Fig.1 Vehicle principle

Hybrid- Pneumatic Vehicle is an eco-friendly vehicle, which uses compressed air along-with batteries (48V 96 amps) which supplies power to the motor of the front wheel having steering mechanism. Various components used in this are 2 stoke air-engine / double-acting cylinder, 4 batteries connected in series, air storage tank, pressure gauge and non-return valve. The chassis of wireframe used is mainly of Chromoly material as it is light in weight and has high strength compared to others. At the back or rear-end of the vehicle, shaft is attached with wheels of a tri-cycle. Chain drive is mounted on it which is used to run air-engine to generate a power with the help of compressor/storage tank at around 7 bar pressure. At the middle of vehicle there is a single person seating provided. On the left side, the engine is placed while to its right is batteries, total of 48 V and 96 amp, to maintain the C.G. For providing initial thrust, batteries are used in order to get stable pick-up which is later switched to compressor/storage tank to drive the vehicle. This vehicle can be further modified for better results.

II. LITERATURE REVIEW

N.A. Todkar *et. al.*[1] 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 non-polluting and economical. We designed 3 wheeled vehicle in order to reduce weight. Unlike conventional transmission systems which include clutch, counter shaft, fly wheel, propeller shaft, differential, the pneumatic motor has been connected and coupled to the rear wheel with the use of an intermediate gear box reducing transmission losses and weight of the vehicle. It also occupies lesser space compared to a four wheeler. But in-depth research is required to completely prove this technology for its commercial as well as technical viability.

Franco Antony *et. al.*[2]for working of an air engine two stroke engine technologies is needed. But the market is now dominated with four stroke engines. So in our project we took a four stroke petrol engine and with some modifications made it into a two stroke air engine. The engine camshaft rotates once for every two rotations of flywheel. For a two stroke it needs one rotation of camshaft for a rotation of the flywheel and for that there must be opening of both inlet and exhaust valves.

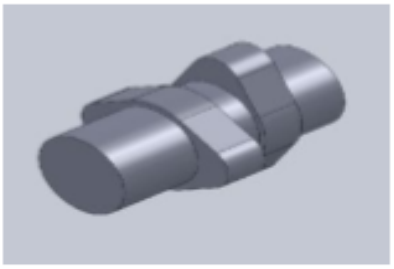

Fig.2 Cam Modified

Alteration of the cam profile with double cam means, for one rotation of camshaft the both valves will open twice. This is done because in a four stroke engine, for two flywheel rotation the camshaft rotates once. So we modify cam profile so that two lift is possible for both inlet and the exhaust sides. Thus for first quarter of a rotation of the camshaft we get power stroke, next quarter exhaust, third quarter again power stroke and fourth again exhaust. This design is adopted by here since there will be no further modifications required in timing gears and cylinder head is needed to accommodate the design. Thus only work to be done is reduced to cam profile.

A compressed air vehicle is powered by an air engines, using compressed air, which is stored in a tank. Instead of mixing fuel with air and burning in the engine it to drive pistons with hot expanding gases; compressed air vehicles (CAV) use the expansion of compressed air to drive their pistons. The use of that air in the engine is 90 per cent efficient. The principle of the air engine is derived from the steam engine in which the pressure energy of steam is converted to kinetic energy. The air engine uses compressed air instead of steam. The compressed air has pressure which on expansion moves the piston (linear motion) which is converted to rotary motion through crank and connecting rod mechanism. In the compressed air engine, the cycle of operation gets completed with two strokes of the piston or one revolution of the crank. The two strokes are:

i. Expansion or Power stroke,

ii. Exhaust stroke

S. S. VermaS.L.I.E.T., Longowal *et. Al.*[3] introduce to the latest developments of a compressed-air vehicle along with an introduction to various problems associated with the technology and their solution. 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.

Dr. S.S. Thipse *et.al.*[4] describes the development of compressed air engine. MDI is one company that holds the international patents for the compressed air engine. . Although it seems to be an environmentally-friendly solution, one must consider its well to wheel efficiency.

B. R. Singh *et.al.*[5]studied about alternative fuel for automobile engines with a special emphasis on compressed air driven engine. In view of the enormous potential of air as working fluid an engine is being designed to run on compressed air

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Saurabh Pathak, Kontham Swetha *et.al.*[6]states 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

S.S. Verma *et.al.*[7]briefly summarize the principle of technology, latest developments, advantages and problems in using compressed air as a source of energy to run vehicles. Compressed air for vehicle propulsion has already being explored and nowadays air powered vehicles are mostly being developed as a more fuel-efficient means of transportation.

D.Ravi *et.al.*[8]analyzed the Climate change and energy security requires a small reduction in travel demand, model shift and technological innovations in the transport sector. . Through a series of press releases and demonstrations, a car using energy stored in the form of compressed air produced by its compressor has been marked as an environmental friendly vehicle of the future.

A.A.Keste *et. al.*[9]describes the working of a vehicle which works on pneumatic power. In this system a double acting pneumatic cylinder is operated as a slider crank mechanism which converts the linear reciprocation of the cylinder piston rod into oscillatory motion of the driver crank about the pinion shaft.

III. MATERIAL SELECTION AND DESIGN CALCULATION

A. Components and Materials

- Piston-Cylinder: A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings.
The main function is force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder.
The pneumatic piston-cylinder materials can be chosen upon job specification. Material range from nickel-plated brass to aluminum, and even steel and stainless steel. Depending on the levels of loads, humidity, temperature, and stoke lengths specified, the appropriate material may be selected.

- Compressor: It is a device that converts power into potential energy stored in pressurized air. 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. The energy contained in the compressed air can be used for a variety of applications, utilising the kinetic energy of the air as it is released and the tank depressurizes. When tank pressure reaches its lower limit, the air compressor turns on again and re-pressurizes the tank.

- Storage Tank: They are containers that hold liquids, compressed gases or mediums used for reservoirs, and for manufactured containers. Storage tanks are often cylindrical in shape, perpendicular to the ground with flat bottoms, and a fixed or floating roof. There are usually environmental regulations applied to the design and operation of storage tanks, often depending on the nature of the fluid contained within.
While steel and concrete remain one of the most popukar choices for tanks, glass-reinforced plastic, thermoplastic and polyethylene tanks are increasing in popularity. They offer lower build cost and greater chemical resistance. There are several standards, such as British standard 4994, DVS (German Welding Institute)2205, and ASME which give advice on wall thickness, quality control procedures, testing procedures, accreditation, fabrication and design criteria of final product.

- Pressure Regulator: A pressure regulator is a valve that automatically cuts off the flow of a liquid or gas at a certain pressure. Regulators are used to allow high-pressure fluid supply lines or tanks to be reduced to safe and usable pressures for various applications.

- Control Valve: They are used to control conditions such as flow, pressure, temperature, and liquid level by fully or partially opening or closing in response to signals received from controllers that compare a setpoint to a process variable whose value is provided by sensors that monitor changes in such conditions. Control Valve is also termed as the Final Control Element.A control valve consists of three main parts in which each part exist in several types and designs: Valve's actuator, Valve's positioned, Valve's body.

- Battery: 4 Batteries of 12V 24 Amps are used for Vehicle. Electric Bike Battery these are highly used in Sightseeing Bus, EV and HEV. These batteries are environment friendly and safe to chargeable. It use for the hybrid vehicle to electric power.

Air Filters: The MDI engine works with air that is taken from the atmosphere and air pre-compressed in tanks.Air is compressed by the on-board compressor or at service stations equipped with a high-pressure compressor. Before compression, the air must be filtered to get rid of any impurities that could damage the engine.Carbon filters are used to eliminate dirt, dust, humidity and other particles which, unfortunately, are found in the air in our cities.

- Compressed Air-Engine: It is 4-stroke petrol engine. We modify this engine into 2-stroke engine by changing its cam shaft. One lobe is also attached to another side of came. So, it reduces the timing of valve and eliminate two stroke (compression and power stroke).We measured rpm and power of the engine.

- Wheels: We used the driving wheel of Yo-bike and used it as the front wheel. As our vehicle is also battery operated so, the battery provides the energy

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for the initial torque and displacement. The back wheels are of tri-cycle.

- AC to DC Convertor: A yo-bike AC to DC converter which converts DC supply of battery to AC supply for acceleration. This motor in placed with the wiring system.

IV. DESIGN AND ANALYSIS OF VEHICLE

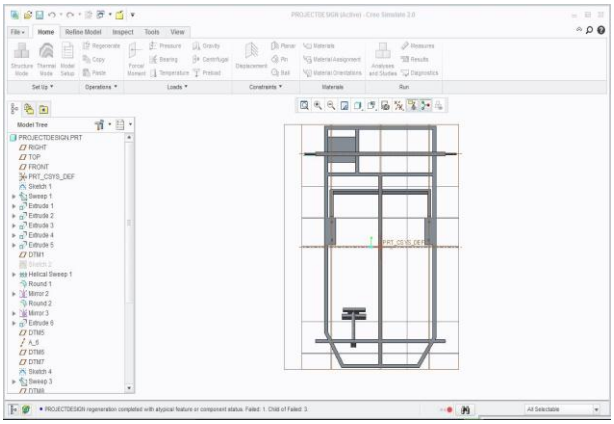

Fig.3 Top view of Initial Design

A. Simulation:

Simulation Type	Static Analysis
Last Modification Date	07-03-2017, 08:57

Table 1: General objective and settings

Name	Steel, Mild, Chromoly	
General	Mass Density	490.059 lbmass/ft^3
	Yield Strength	30.023 ksi
	Ultimate Tensile Strength	50.038 ksi
Stress	Young's Modulus	31908.302 ksi
	Poisson's Ratio	0.275 ul

Table 2: Materials

Name		Minimum	Maximum
Displacement		0.000 in	0.895 in
Forces	Fx	-0.000 lbforce	0.000 lbforce
	Fy	-1892.012 lbforce	1892.012 lbforce
	Fz	-0.000 lbforce	0.000 lbforce
Moments	Mx	-11916.386 lbforce in	11916.385 lbforce in
	My	-0.000 lbforce in	0.000 lbforce in
	Mz	-4.059 lbforce in	3.657 lbforce in
Normal Stresses	Smax	0.000 ksi	220.028 ksi
	Smin	-220.028 ksi	0.000 ksi
	Smax(Mx)	0.000 ksi	220.028 ksi
	Smin(Mx)	-220.028 ksi	0.000 ksi
	Smax(My)	-0.000 ksi	0.000 ksi
	Smin(My)	-0.000 ksi	0.000 ksi
	Saxial	-0.000 ksi	0.000 ksi
Shear Stresses	Tx	-0.000 ksi	0.000 ksi
	Ty	-6.004 ksi	6.004 ksi
Torsional Stresses	T	-0.054 ksi	0.060 ksi

Table 3: Static Result Summary

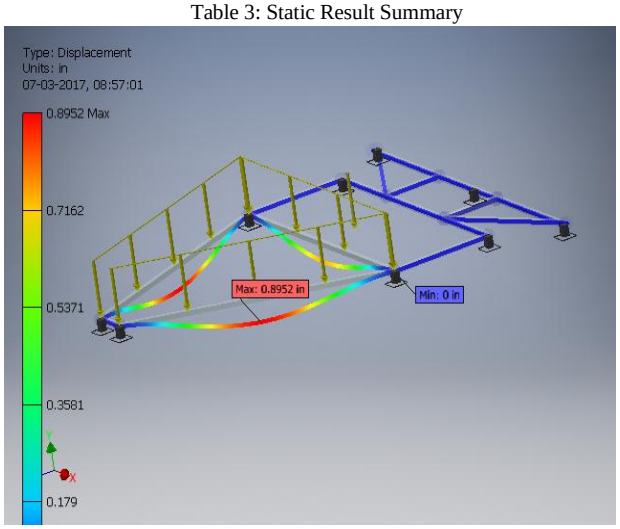

Fig.4 Displacement Simulation Results

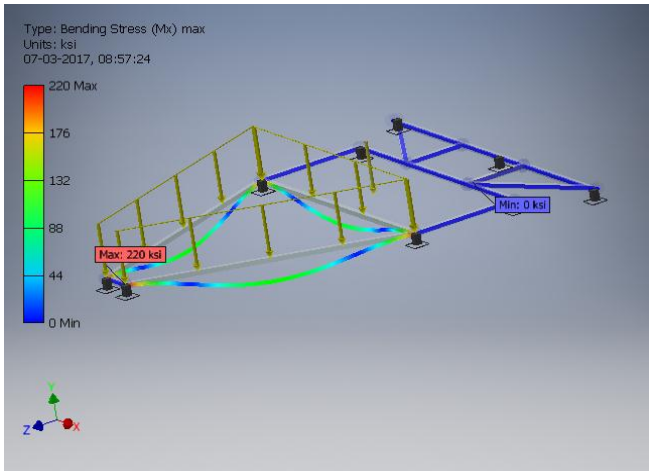

Fig.5 Bending Simulation Results

V. CALCULATIONS AND TESTING

- Minimum required pressure to run engine = 4 bar
- Maximum speed of engine at no load condition = 1,500 rpm
- Maximum speed of engine at load of 3kg on dynamometer = 700 rpm

Load, m Frictional Force is;

$$F_f = m \times g \times \mu$$

Where,
F = 150 kg
Gravitational force, g = 9.81

Coefficient of friction between wheel and road, μ = 0.6
882.9 N
Required Force;

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Fig.6 Manufacturing of Pneumatic Vehicle

$F_r = {}^{\pi}/_{4} \times d^2 \times p$

Where, diameter of piston, d = 0.06 m

Pressure, p = 6.5

F = 1,837.83 N, (which is more than frictional force, so it allows vehicle to run)

Calculation of Power;

$P = F \times v$

Where, velocity, v = 1

Force, F = 1,471.5 N

P = 1.5 kW, this power is required to drive the motor.

A. Hydraulic Test For Tank

A hydrostatic test is a way in which pressure vessels such as fuel tanks can be tested for strength and leaks. The test involves filling the vessel or pipe system with a liquid, usually water, which may be dyed to aid in visual leak detection, and pressurization of the vessel to the specified test pressure. Pressure tightness can be tested by shutting off the supply valve and observing whether there is a pressure loss. The location of a leak can be visually identified more easily if the water contains a colorant. Strength is usually tested by measuring permanent deformation of the container. Hydrostatic testing is the most common method employed for testing pipes and pressure vessels. Using this test helps maintain safety standards and durability of a vessel over time.

B. Engine Torque Test

First we mount the engine on the platform. After that we attached plate with the engine & drilled this plate. Moreover after completing the engine mounting we start our test with the rope break 2 dynamometers of 50kg each. We started our engine on no load condition while compressor gives the 6 bar pressure. After applying load gradually, we calculated our torque of engine with the different conditions. The results were 700 rpm after applying load.

VI. APPLICATION

- Offices, institutions, industries etc, can use the vehicle for smaller to and fro movements.
- The system eliminates the need for fuel, making it eco-friendly and pollution free, thus can be used for personal as well as commercial use.
- No conventional fuel is needed except the use of batteries for initial thrust and speed, hence has more life and less costly.

VII. ADVANTAGES

- Also light in weight (approx 200 kg) due to use of composite material, with attractive looks.
- In conjunction with compressed air it also runs on batteries.
- The pneumatic vehicle is equipped with a range of modern systems. For example, one mechanism stops the engine when the vehicle is stationary i.e. at traffic lights, junctions etc. Unlike conventional vehicle, the engine does not operate in traffic jams, which thus saves on fuel.
- Another interesting feature is the pneumatic system. When the vehicle brakes, the kinetic energy from braking is used to drive a pump that helps to restore some of the lost pressure.

VIII. OVERALL REAL COSTING OF VEHICLE

Since, the Pneumatic Vehicle uses only air as the fuel, the cost of the fuel will not be there as air is abundantly available. Further, 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, non-polluting. The technology involved with compressed air reduces the production costs of vehicles with 20% because it is not necessary to assemble a cooling system, a fuel tank, spark plugs or mufflers.

Pneumatic Vehicles are having lower initial cost than battery electric vehicles when mass produced. Pneumatic air is not subject to fuel tax.The cost of the carbon-fibre tank having capacity of 90 meter cube is around Rs. 180,000. According to an agreement between Tata Motors and MDI, a Pneumatic Air Car named Air-Pod was costing around Rs 6 Lakhs.

IX. CONCLUSION

The pneumatic-hybrid vehicle is one of the treasures to automobile industry. It promises a better combination of different power sources along-with contribution to the field of green technology. The air-hybrids are easy to manufacture and can be easily driven without any carbon footprints. So, for a better tomorrow, pneumatic-hybrid has its role. Thus, for green technology, pneumatic-hybrid is a boon. This achievement is a major break-through in battle to create greener and cheaper motoring. The result is new low-cost pneumatic-hybrid which significantly cuts emission of carbon-dioxide. Existing green-hybrid cars such as Toyota-Prius and Honda-Insight, use petrol engine and braking energy to generate onboard electricity to give supplementary power to the vehicle. Our vehicle uses similar principle, but instead there is no scope of entering of braking energy and can be worked in future. Thus, an efficient greener technology is guaranteed for the future with our project.

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The system eliminates the need for fuel, making the environmental pollution-free. The compressed air drives air motor, which turns the vehicles wheels, once compressed, the air is stored in tank. The air is used when vehicle needs energy, such as for starting up and acceleration. In future we are able to use vehicle with various modifications like increasing tank capacity; using composite materials of high strength; weight of parts like chassis, storage tank, etc, reduces which results in low weight of vehicle; reducing losses of air flow through nozzles, pipes, etc. With above modifications it is possible to increase the performance and distance achieved by vehicle.

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