DEVELOPMENT OF COMPRESS AIR TRANSPORTATION (CAT) FOR ALTERNATIVE ENERGY UTILIZATION

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ABSTRACT

Compress Air Transportation (CAT) is a new concept of transportation that utilizes air as the source of energy. Work on alternative power system for vehicle is becoming very important for the future due to combination of high prices on fuel, emission factor and also the source of the current energy will eventually run out. Several advantages for utilizing air as the source of energy compared to other alternative energy sources makes it become the subject for this project. In this project, a simple transportation utilizing air as the source of energy has been developed. The main component of the engine of the CAT is a device called the "Air Impact Wrench" which can be purchased from local stores. The CAT was tested and analyzed for further studies on expanding this new technology.

ABTSRAK

Compress Air Transportation (CAT) adalah suatu pengangkutan konsep baru yang mengimplikasikan udara sebagai sumber tenaga bagi menggerakkannya. Rekacipta dan kerja pada tenaga alternatif untuk kenderaan menjadi sesuatu yang sangat penting untuk masa hadapan kerana harga minyak yang tinggi, faktor pencemaran dan juga sumber bahan api sekarang akan habis tidak lama lagi. Beberapa kebaikan didalam menggunakan udara sebagai sumber tenaga berbanding dengan sumber tenaga alternative yang lain menjadikan ia sebagai subjek untuk projek ini. Di dalam projek ini, suatu kenderaan ringkas yang menggunakan udara telah dihasilkan. Komponen utama enjin CAT adalah "Air Impact Wrench" yang boleh didapati di pasaran. CAT telah diuji dan dianalisis untuk kajian dalam mengembangkan teknologi baru ini.

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LIST OF SYMBOLS

P	Pressure
M	mass
ρ	Density
σ	stress
V	Volume
r	Radius
t	Thickness
F	Force
A	Area
a	Acceleration
T	Torque

CHAPTER 1

INTRODUCTION

1.1 Background

The price of fuel has soared in the recent years. Petroleum, which has been the main source of fuel for the history of cars, is becoming more and more expensive and impractical (especially from an environmental standpoint).

While Petrol prices in Malaysia have not yet reached their highest point (RM1.62 per liter for RON97 in July 2005), they have climbed steeply in the past year. In 2006, prices rose up to RM1.92 per liter, which was the highest price of petrol in the history of Malaysia. [1]

But cost is not the only problem with using petrol as our primary fuel. It is also damaging to the environment, and since it is not a renewable resource, it will eventually run out.

One possible alternative is the air-powered car. In this project, we will study and develop a simple and basic Compress Air Transportation (CAT) which will eventually be a starting point of new alternative energy utilization for transportation in the future.

1.2 Objectives

The purpose of this project is to study on developing and fabricating a transportation which utilizes compressed air as the source of energy.

1.3 Scopes of Project

The scope of the project:

i. Research on alternative energy vehicles and compress air technology to collect the data as requirement in the literature review.
ii. Design a transportation that can move using the energy from compressed air.
iii. Fabricate and assemble all parts of the Compress Air Transportation (CAT)
iv. Make an analysis and collect data after completing the fabrication for further studies in improving this new technology

1.4 Problem Statement

A traditional car's engine uses up to about 65% of the energy potentially available from the fuel, just to move all its parts such as pistons and cams, plus what is wasted generating excess heat. Then the transmission uses 6%, the accessory load 2% and idling losses come to about 11%, leaving about 16% of the energy actually engaged in making the wheels turn. Because of the weight of all these structures, the engine block, crankshaft, gears, transmission, etc., that 16% of the energy is having to move a vehicle weighing perhaps a ton and a half – which may have only one person sitting in it, weighing only 150 lb. [2]The key problem from the current design is:

i. The current engine design of a vehicle is too complex. The main purpose of designing a vehicle is to get the wheels to turn, preferably with as little wasted motion and energy as possible.

ii. The source of current energy which is from petroleum is too costly, and it is not a renewable source, which will eventually run out. It also releases emissions which will cause damage to the environment.

1.4 Propose design solution

The purpose of this study is to develop a new design concept vehicle that can:

i. Change the main source of energy to an alternative energy which can reduce the cost and also make zero pollution.
ii. Utilize a simple device to move the vehicle with high efficiency and low amount of waste energy.

1.5 Expected outcome

Develop a vehicle that can move with using energy from compressed air with the speed of 50 km/hr to move for a distance of 1000 meters.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Alternative Energy Vehicle refers to a vehicle that run on energy other than traditional gasoline or diesel; any method of powering an engine that does not involve petroleum. Due to a combination of high prices on fuel, emission factor and also the source of the current energy will eventually run out, work on alternative power systems for vehicles is very important for the future.

2.2 Alternative Energy Vehicle

In today's technology, there are many vehicles that use alternative energy as the source of energy. The current design on alternative energy for vehicles will be discussed in this section.

2.2.1 Air Car

The air engine is an emission-free piston engine that uses compressed air as a source of energy. The first compressed air car was invented by a French engineer named Guy Nègre.

The expansion of compressed air may be used to drive the pistons in a modified piston engine. Efficiency of operation is gained through the use of environmental heat at normal temperature to warm the otherwise cold expanded air from the storage tank. This non-adiabatic expansion has the potential to greatly increase the efficiency of the machine. The only exhaust is cold air (−15 °C), which could also be used to air condition the car. The source for air is a pressurized carbon-fiber tank holding air at 3,000 lbf/in^2 (20 MPa). Air is delivered to the engine via a rather conventional injection system. Unique crank design within the engine increases the time during which the air charge is warmed from ambient sources and a two stage process allows improved heat transfer rates.

This engine was used to power an urban car with room for five passengers and a projected range of about 100 to 200 miles (160 to 320 km), depending on traffic conditions. The main advantages are: no roadside emissions, low cost technology, engine uses food oil for lubrication (just about 1 liter, changes only every 30,000 miles (50,000 km)) and integrated air conditioning. Range could be quickly tripled, since there are already carbon fiber tanks which have passed safety standards holding gas at 10,000 lbf/in^2 (70 MPa).

The tanks may be refilled in about three minutes at a service station, or in a few hours at home plugging the car into the electric grid via an on-board compressor. The cost of refilling is projected to be about US$3.

2.2.2 Liquid Nitrogen Car

Liquid nitrogen (LN2) is a method of storing energy. Energy is used to liquify air, and then LN2 is produced by evaporation, and distributed. LN2 is exposed to ambient heat in the car and the resulting nitrogen gas can be used to power a piston or turbine engine. The maximum amount of energy that can be extracted from 1 kg of LN2 is 213 W-hr or 173 W-hr per liter, in which a maximum of 70 W-hr can be utilized with an isothermal expansion process. Such a vehicle can achieve ranges similar to that of gasoline with a 350 liter (90 gallon) tank. Theoretical future engines, using cascading topping cycles, can improve this to around 110 W-hr/kg with a quasi-isothermal expansion process. The advantages are zero harmful emissions and superior energy densities than compressed air, and a car powered by LN2 can be refilled in a matter of minutes.

2.2.3 Alcohol/Ethanol

The use of alcohol as a fuel for internal combustion engines, either alone or in combination with other fuels, has been given much attention mostly because of its possible environmental and long-term economical advantages over fossil fuel.

Both ethanol and methanol have been considered for this purpose. While both can be obtained from petroleum or natural gas, ethanol may be the most interesting because many believe it to be a renewable resource, easily obtained from sugar or starch in crops and other agricultural product such as grain, sugarcane or even lactose. Since ethanol occurs in nature whenever yeast happens to find a sugar solution such as overripe fruit, most organisms have evolved some tolerance to ethanol, whereas methanol is toxic. Other experiments involve butanol, which can also be produced by fermentation of plants.

Use of pure ethanol and ethanol/gasoline mixtures is not without problems however. Ethanol has the unfortunate property of slowly decomposing certain rubber compounds such as are found in the fuel lines and seals in vehicles produced before the mid 1980's. There are claims that even E10 can have a significantly deleterious effect on older vehicles and after prolonged use may cause dangerous fuel leaks in affected cars. Because gasoline is more volatile than Ethanol, it can be harder to start some engines using higher Ethanol percentages than they were designed to use - especially when the engine is cold - and even modern vehicles may be unable to run more than 20% ethanol for this reason. Because of the difficulty of starting engines using ethanol, it is common practice in E100 countries such as Brazil to have a small gasoline reservoir in addition to the normal fuel tank with a switch to allow the driver to switch over to gasoline when the car has difficulties starting on ethanol alone. Ethanol is also electrically conductive (gasoline is an effective insulator) which can cause problems with some early electric fuel pump designs and fuel tank sensors. Corrosion of magnesium and aluminium parts is also a concern at higher ethanol percentages. Ethanol has less energy per volume than gasoline so miles-per-gallon ratings with ethanol mixtures are significantly worse than with pure gasoline - although ethanol has a higher octane rating which is beneficial to high compression ratio engines.

Many cars that currently use gasoline can run on ethanol, a fuel made from plant sugars. Most cars that are designed to run on gasoline are capable of running with up to 15% ethanol mixed into gasoline. With a small amount of redesign, gasoline-powered vehicles can run on ethanol concentrations as high as 85%. Most gasoline fuelled vehicles can be modified to run on LPG but there has been some concern that the ethanol-gasoline mixtures prematurely wear down seals and gaskets. Theoretically, the lower energy content of alcohol should lead to considerably reduced efficiency and range when compared with gasoline. However, EPA testing has actually shown only a 20-30% reduction in range. Therefore, if the vehicle is capable of doing 750 kilometers on a 50 liter tank (15 kilometers per liter), its range would be reduced to approximately 600 kilometers (12 kilometers per liter). Measures are available to increase this efficiency, such as different camshaft configurations, altering the timing/spark output of the ignition, increasing compression, or simply using a larger fuel tank.

2.2.4 Battery-electric

Battery Electric Vehicles (BEVs) are electric vehicles whose main energy storage is in the chemical energy of batteries. BEVs are the most common form of what is defined by the California Air Resources Board (CARB) as zero emission (ZEV) passenger automobiles, because they produce no emissions while being driven. The electrical energy carried onboard a BEV to power the motors is obtained from a variety of battery chemistries arranged into battery packs. For additional range genset trailers or pusher trailers are sometimes used, forming a type of hybrid vehicle. Batteries used in electric vehicles include "flooded" lead-acid, absorbed glass mat, NiCd, nickel metal hydride, Li-ion, Li-poly and zinc-air batteries.

Attempts at building viable, modern battery-powered electric vehicle began in the 1950s with the introduction of the first modern (transistor controlled) electric car - the Henney Kilowatt. Despite the poor sales of the early battery-powered vehicles, development of various battery-powered vehicles continued through the 1990s (notably General Motors with the EV1), but cost, speed and inadequate driving range continued to make them impractical. Battery powered cars have primarily used lead-acid batteries and NiMH batteries. Lead-acid batteries' recharge capacity is considerably reduced if they're discharged beyond 75% on a regular basis, making them a less-than-ideal solution. NiMH batteries are a better choice, but are considerably more expensive than lead-acid. Lithium-ion battery powered vehicles such as the Venturi Fetish have recently demonstrated excellent performance and range, but they remain very expensive.

2.2.5 Biodiesel

The main benefit of Diesel combustion engines is that they have a 50% fuel burn efficiency; compared with just 23% in the best gasoline engines. This makes Diesel engines capable of achieving much better fuel efficiency than gasoline vehicles.

Biodiesel is commercially available in most oilseed-producing states in the United States. As of 2005, it is somewhat more expensive than fossil diesel, though it is still commonly produced in relatively small quantities (in comparison to petroleum products and ethanol). Many farmers who raise oilseeds use a biodiesel blend in tractors and equipment as a matter of policy, to foster production of biodiesel and raise public awareness. It is sometimes easier to find biodiesel in rural areas than in cities.

Some Diesel-powered cars can run with little or no modification on 100% pure biodiesel, a fuel that can be made from vegetable oils. Vegetable oils tend to solidify in cold weather conditions so vehicle modifications may be required in order to heat the fuel prior to use under those circumstances. Modern low emission diesels (most often Euro -3 and -4 compliant), typical of the current production in the European industry, require extensive modification of injector system, pumps and seals etc. due to the higher operating pressures. The result is sensitive lubrication & sealing systems that bio diesel fuels do not protect and may even attack. This reduces the market for biodiesels as increasing numbers of new vehicles are not able to use it.

2.2.6 Biogas

Compressed Biogas may be used for Internal Combustion Engines after purification of the raw gas. The removal of H2O, H2S and particles can be seen as standard producing a gas which has the same quality as Compressed Natural Gas. The use of biogas is particularly interesting for climates where the waste heat of a biogas powered power plant cannot be used during the summer.

2.2.7 Flexible fuel

A flexible-fuel vehicle or dual-fuel vehicle is an automobile or truck (lorry) that can typically alternate between two sources of fuel. A common example is a vehicle that can accept gasoline mixed with varying levels of ethanol (gasohol). Some cars carry a natural gas tank and one can switch from gasoline to gas.

North American vehicles from approximately 1980 onward can run on 10% ethanol/90% gasoline (e.g., E10) with no modifications. Prior to 1980, many cars imported into the United States contained rubber, aluminium, and other materials that were generally non-compatible with any ethanol in their fuel delivery systems, and these cars experienced problems when E10 was first introduced. American made cars from the late 1970's onward can run on E10 with no modifications. E10 fuel is widely available. Going beyond 10% ethanol generally requires special engineering.

2.2.8 Hybrid Electric

A hybrid vehicle uses multiple propulsion systems to provide motive power. This most commonly refers to gasoline-electric hybrid vehicles, which use gasoline and electric batteries for the energy used to power internal-combustion engines and electric motors. These powerplants are usually relatively small and would be considered "underpowered" by themselves, but they can provide a normal driving experience when used in combination during acceleration and other maneuvers that require greater power.

The Toyota Prius is one of the world's first commercially mass-produced and marketed hybrid automobiles. Manufactured by Toyota, the Prius first went on sale in Japan in 1997. The car was introduced to the worldwide market in 2000 and almost 160,000 units had been produced for sale in Japan, Europe, and North America as of the end of 2003.

The Honda Insight is a 2-seater hatchback hybrid automobile manufactured by Honda. It was the first mass-produced hybrid automobile sold in the United States, introduced in 1999. According to the EPA, the 5-speed manual transmission variant of the Insight is the most fuel-efficient mass-produced automobile sold in the United States.

2.2.9 Hydrogen

A hydrogen car is an automobile which uses hydrogen as its primary source of power for locomotion. These cars generally use the hydrogen in one of two methods: combustion or fuel-cell conversion. In combustion, the hydrogen is "burned" in engines in fundamentally the same method as traditional gasoline cars. In fuel-cell conversion, the hydrogen is turned into electricity through fuel cells which then powers electric motors. With either method, the only byproduct from the spent hydrogen is water.

A small number of prototype hydrogen cars currently exist, and a significant amount of research is underway to make the technology more viable. The common internal combustion engine, usually fueled with gasoline (petrol) or diesel liquids, can be converted to run on gaseous hydrogen. However, the most efficient use of hydrogen involves the use of fuel cells and electric motors instead of a traditional engine. Hydrogen reacts with oxygen inside the fuel cells, which produces electricity to power the motors. One primary area of research is hydrogen storage, to try to increase the range of hydrogen vehicles while reducing the weight, energy consumption, and complexity of the storage systems. Two primary methods of storage are metal hydrides and compression. Some believe that hydrogen cars will never be economically viable and that the emphasis on this technology is a diversion from the development and popularization of more efficient hybrid cars and other alternative technologies.

High speed cars, buses, submarines, and space rockets already run on hydrogen, in various forms. There is even a working toy model car that runs on solar power, using a reversible fuel cell to store energy in the form of hydrogen and oxygen gas. It can then convert the fuel back into water to release the solar energy.

BMW's Clean Energy internal combustion hydrogen car has more power and is faster than hydrogen fuel cell electric cars. A limited series production of the 7 Series Saloon was announced as commencing at the end of 2006. A BMW hydrogen prototype (H2R) using the driveline of this model broke the speed record for hydrogen cars at 300 km/h (186 mi/h), making automotive history. Mazda has developed Wankel engines to burn hydrogen. The Wankel uses a rotary principle of operation, so the hydrogen burns in a different part of the engine from the intake. This reduces pre-detonation, a problem with hydrogen fueled piston engines.

2.2.10 Solar

A solar car is an electric vehicle powered by solar energy obtained from solar panels on the car. Solar cars are not a practical form of transportation; insufficient power falls on the roof of a practically sized and shaped vehicle to provide adequate performance. They are raced in competitions such as the World Solar Challenge and the American Solar Challenge. These events are often sponsored by Government agencies such as the United States Department of Energy keen to promote the development of alternative energy technology such as solar cells and electric vehicles. Such challenges are often entered by universities to develop their students engineering and technological skills as well as motor vehicle manufacturers such as General Motors and Honda.

2.2.11 Steam

A steam car is a car that has a steam engine. Wood, coal, ethanol, or others can be used as fuel. The fuel is burned in a boiler and the heat converts water into steam. When the water turns to steam, it expands. The expansion creates pressure. The pressure pushes the pistons back and forth. This turns the driveshaft to spin the wheels forward. It works like a coal-fueled steam train, or steam boat. The steam car was the next logical step in independent transport.

Steam cars take a long time to start, but some can reach speeds over 100 mph (161 km/h) eventually. A steam engine uses external combustion, as opposed to internal combustion. Gasoline-powered cars are more efficient at about 25-28% efficiency. In theory, a combined cycle steam engine in which the burning material is first used to drive a gas turbine can produce 50% to 60% efficiency. However, practical examples of steam engine cars work at only around 5-8% efficiency.

2.3 Studies on Current Air Engine

The air engine is an emission-free piston engine using compressed air. The engines are similar to steam engines as they use the expansion of externally supplied pressurized gas to perform work against a piston.

The most recent development uses pressurized air as fuel in an engine invented by Guy Nègre, a French engineer. A similar concept is currently being developed by the Uruguayan engineer Armando Regusci, an Australian Angelo Di Pietro and a South

Korea Chul-Seung Cho. Despite interest in the technology, no company has yet put a vehicle using this technology into mass production. A successful vehicle would offer many of the advantages of a battery electric vehicle with the additional ability to quickly restore the stored energy - in a few minutes rather than the hours required to recharge batteries.

2.3.1 History

The air engine and its concept to use air as an energy carrier is not new. It was used in old times (19th century) to power mine locomotives. After this, it was used (and is still being used) in car racing to give the first power to start the car's main power plant, the internal combustion engine (ICE).

In 1991 the inventor Guy Nègre started up a company called MDI and invented a dual-energy engine running on both compressed air as on regular fuel. From this moment on he managed to create a compressed air only-engine, and improved his design to make it more powerful. In the 15 years he's been working on this engine, considerable progress has been made: the engine is now claimed to be competitive with modern ICEs. It is probably still not as powerful as an ICE (although depending on which model of air engine vs. model ICE). Proponents claim that this is of little importance since the car can simply be made lighter, or the tanks be put on a higher pressure, pushing the engine to above a comparable ICE-engine.

Other people that have been working on the idea, among them Armando Regusci, Angelo Di Pietro and Chul-Seung Cho which also have their own companies, Rugusci's RegusciAir, Di Pietro's Engine Air and Chul-Seung Cho's Energine.

2.3.2 Engine Design

It uses the expansion of compressed air to drive the pistons in a modified piston engine. Efficiency of operation is gained through the use of environmental heat at normal temperature to warm the otherwise cold expanded air from the storage tank. This non-adiabatic expansion has the potential to greatly increase the efficiency of the machine. The only exhaust gas is cold air (−15 °C), which may also be used for air conditioning in a car. The source for air is a pressurized carbon-fiber tank holding air at around 20 MPa (3,000 psi, 200 bar). Air is delivered to the engine via a rather conventional injection system. Unique crank design within the engine increases the time during which the air charge is warmed from ambient sources and a two stage process allows improved heat transfer rates.

The Armando Regusci's version of the air engine has several advantages over the original Guy Nègre's one. In original Guy Nègre's air engine, one piston compresses air from the atmosphere, holding it on a small container that feeds the high pressure air tanks with a small amount of air. Then that portion of the air is sent to the second piston where it works. During compression for heating it up, there is a loss of energy due to the fact that it cannot receive energy from the atmosphere as the atmosphere is less warm than it. Also, it has to expand as it has the crank. The Guy Nègre's air engine works with constant torque, and the only way to change the torque to the wheels is to use a pulley transmission of constant variation, losing efficiency. In the Regusci's version, the transmission system is direct to the wheel, and has variable torque from zero to the maximum with all the efficiency. When vehicle is stopped, Guy Nègre's engine has to be on and working, losing energy, while the Regusci's version has not.

In July 2004, Guy Nègre abandoned his original design, and showed later a new design where he stated to have it invented back in year 2001, but his new design is identical to the Armando Regusci's air engine which was patented back in 1989 (Uruguay) with the patent number 22976, and back in 1990 (Argentina). In those same patents, it is mentioned the use of electrical motors to compress air in the tanks.