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Research Article

HYDROGEN FUELD FOUR STROKE FOUR CYLINDER DIESEL ENGINE

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Abstract

In the past few years automotive companies have been searching for technological advantages to increase fuel millage in order to protect the environment, while still providing an enjoyable driving experience for their customers. With gas prices on the rise, the average American wants a car that can do everyday activities whilst spending the least amount of fuel possible. Not only customers are demanding for better gas millage, but the government as well. In fact, president Obama passed the Fuel Economy Reform Act, which states that by the year 2025 new cars are to have gas millage of 54.5 miles per gallon. In our senior thesis we will attempt to address this issue by designing and building an HHO generator. This generator uses the principle of electrolysis to split water into its two molecules, hydrogen and oxygen, in gas form. This gas will be introduced into the combustion chamber of an engine to increase its power, burn less gas, and exhaust water particles out to the environment. "Water fueled HHO technology has the ability to clean up our environment and is also beneficial for the vehicle's mileage"

Keywords Hydrogen fueld, Engine.

Introduction

Problem statement

With such high demand for more efficient engines, our mission is to design and create a device that will increase engine efficiency without jeopardizing its performance. Such device is an HHO Generator. This generator uses electric current (electrolysis) to yield hydrogen from water. There are two different ways to run the hydrogen into the engine. The first and most ambitious way to this is to send it through the injectors, while shutting off the fuel line. This will only be done if the system is self-sustained, meaning the car is able to run on hydrogen only. If this is not accomplished due to thermodynamic restrictions, then the hydrogen will be introduced into the combustion chamber of the engine through the intake manifold. We will attempt to make the generator compact and affordable, in order for it to be appealing tocustomers. Building this generator comes with some challenges. We need to make sure that the amount of energy put into the cell to split the water molecules is less than the amount of output energy of the generator. In order to overcome this challenge we will need to make it as efficient as possible. This includes coming up with a creative design to get as much hydrogen out, with the least amount of current running through the cell. More concerns include implementing very conductive wires and metals into our system. Taking these aspects into consideration will make the HHO generator a productive addition to any internal combustion engine.

Motivation

Some car manufactures around the world are developing hydrogen-fueled technologies. Due to the high demand of oil and its main associated problems for the environment, such as air pollution and gas emissions, some companies such as BMW, Honda and Mazda are developing cars powered by hydrogen fueled internal combustion engines (H2ICEs). These systems are different from what the HHO generator does. Hydrogen cell vehicles replace fuel with hydrogen. This means that they have a tank to store hydrogen, which has to be filled periodically. This comes with some complications. One of which is the lack of hydrogen stations around cities, which makes it uneasy to find, and due to low demand it's expensive to obtain. Another setback is that it is very dangerous to drive with a tank full of hydrogen in your car. Hydrogen is extremely explosive and in the case of a crash, the tank could explode, this could be catastrophic. On the other hand, an HHO generator powered vehicle is much safer since the hydrogen is being produced on-demand and is immediately consumed by the engine. This solves the two main problems that hydrogen cell vehicles come with. Moreover, this kind of generator could easily be implemented in any car, with some minor modifications. Dual-fuel internal combustion engine vehicles that combine gasoline and hydrogen could be the alternative solution to our environmental problems. Vehicle conversion to dual-fuel operation is technically feasible and low cost. Moreover, some states award tax credits for installing hybrid hydrogen upgrades. It is the simplicity of this design, as well as the positive environmental effects that come with HHO generators that is motivating us to pursue this project.

Literature review

Water electrolysis is one of the most clean, simple, and intuitive procedures to yield hydrogen. Such process, discovered by M. Faraday in 1820, consists of decomposing water into its constitutional components, oxygen and hydrogen, by means of electric current. Using water electrolysis to produce hydrogen has been studied for a long time. Some records indicate that hydrogen has been used by man as an alternative fuel source in many different levels of fields such as commercial, military and industrial sectors since the late 19th century. Electrolysis is a favored field of study for scientific experiments for many researchers all around the

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world. The process of electrolysis works with an electrical power source that is connected to two electrodes that are made out of typical metal (such as stainless steel, platinum or, titanium), which are submerged in water enhanced with electrolytes. Hydrogen will be produced at the negatively charged electrode (cathode), while oxygen will be produced at the positively charged electrode (anode). Ideally the amount of hydrogen produced is twice the amount of the oxygen moles. The half-reaction equation below shows the electrolysis process

Anode: $2H_2O(l) \rightarrow O_2(g)+4H^+(aq)+4_e^-$

$$= \frac{\text{Cathode: } 2H^+(aq) + 2e^- \rightarrow H_2(g)}{\text{Overall: } 2H_2O(l) \rightarrow O_2(g) + 2H_2(g)}$$

Construction requirements

The manufacturing of this hydrogen system will require a series of machining. A milling machine is used in order to drill holes on the bottom of the vessel. This is where the tubes are going to be extended out of the container in order to connect the wires for the current. This will allow for the electricity to be outside of the vessel, while the highly flammable HHO gas is stored inside the container, making it safer. Moreover, a band saw will be used to cut the stainless steel tubes to the desired lengths. Other construction requirements include, making sure the hydrogen gas is well contained to prevent leaks. For this, sturdy hoses or pipes will be used with secured ends. Additionally, no hydrogen will be stored. The engine will consume it almost immediately after the process of electrolysis is completed. Another requirement includes the use of an amp-meter to control the amount of current use to produce the HHO gas, as well as the use of a PWM (pulse width modulator) to adjust the frequency of the current in order to decrease the amount of amperes needed for the water breakdown. The most important of the requirements is the implementation of EFIE (electronic fuel injection enhancer), this apparatus is connected between the module and the MAF (mass air flow) sensor of the car. It uses a circuit that allows the driver to adjust the voltage reading manually from the sensor and controls the amount of gas injected in the combustion chamber depending on the driving condition and the amount of gas the produced by the generator. Every car equipped with fuel injection system uses a MAF sensor in order to register how much air is flowing across the air intake manifold to regulate how much gas is needed to produce a perfect mixture.

Working principle

1. Design and build a practical and economical way to increase engine efficiency in combustion engines.
2. Build HHO generator that splits water's molecules, using the process of electrolysis. Yielding a mixture of hydrogen and oxygen gas, also known as HHO gas.
3. Adapt the generator in a conventional internal combustion engine to push the HHO gas either through the injectors, or if the system is not fully sustained with hydrogen, through the air intake to have a mixture of air, hydrogen, and gasoline.
4. Overcome the energy loss that is used in the process of electrolysis with a higher power output by the engine.
5. Try our best to generate hydrogen efficiently enough to have the car run only on HHO gas.
6. If the system is not self-sustained with HHO gas only, then improve its performance and gas millage with such gas.

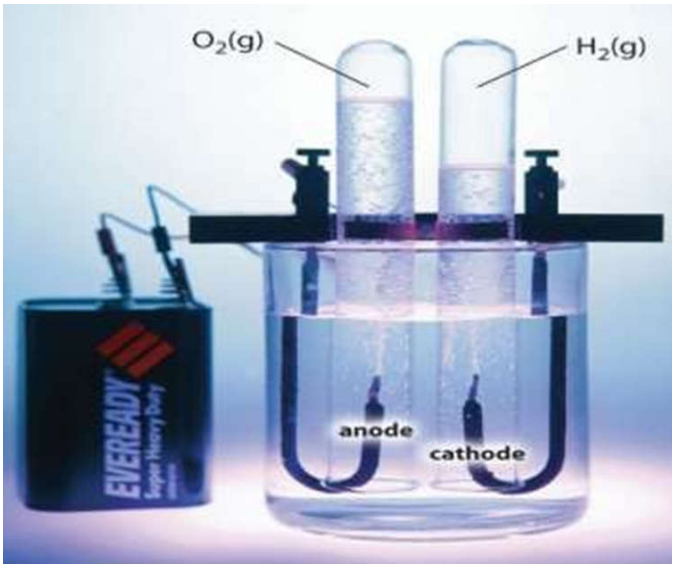

Figure 1. Electrolysis Photograph

Concept design

An option for the design is to use a Hydrogen (HHO) Generator which can improve fuel economy on any gasoline, Diesel, or LPG vehicle Concept Hydrogen Generator. There are research groups that make these systems using electricity from your vehicle's alternator in order to transform water into hydroxy gas while you drive. This gas is then fed into the engine delivering a cleaner, more efficient combustion. With this innovative Hydrogen on-demand technology you will use less fuel and save money. This kind of HHO generators uses 12 volt batteries to power electrolysis. There are other methods of obtaining hydrogen through water, such as chemical methods. These yield a high output of PURE H2. With chemical generation no electricity is required. It works on a simple and very inexpensive chemical reaction using aluminum and water. Each gram of aluminum can react to produce 1.2 liters of hydrogen at standard atmospheric pressure. These kinds of organizations are dedicated to the research and development of Fuel Saving Technologies. However, this concept is not the industry's most efficient, but it is an affordable HHO supplementation system. Methods, electrolysis and chemical methods are compatible with each other. They work on most types of engines and are easily installed on vehicles.

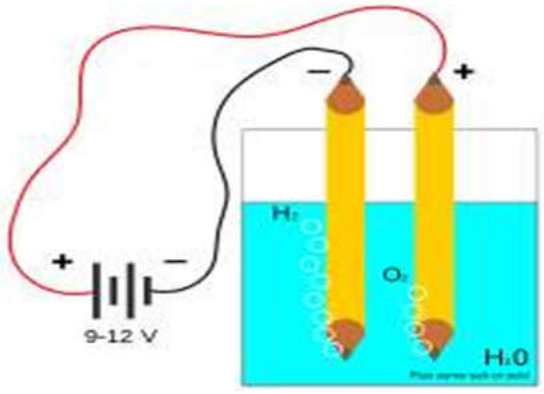

Figure 2. Principle of Electrolysis

Major components

- 12v battery
- Ignition switch
- 30 amp relay
- Relay ground

The main component in a Hydrogen-on-Demand system is the HHO or Hydroxy gas generator. This device can be a simple one-cell unit or have as many cells as needed to produce the quantity of HHO gas desired. Electric current is the driving force that creates electrolysis in such generator. It separates chemically bonded compounds in water by passing an electric current through them. By adding an electrolyte to the water, the electrolysis process can be enhanced. An electrolyte is any substance containing free ions that behaves as an electrically conductive medium. Catalyst, would be the correct term because of the function it performs to speed up the production of HHO gas. Another important component for regulation is the Amp Meter, this is a tool used to measure the amperage flowing through a wire or other conductive material. It is a very important tool for this project, because the amount of amps sent to the cell determines the amount of HHO gas generated. The final major component of our design is a vessel that's big and sturdy enough in which to conduct electrolysis in. It has to be able to maintain high enough pressure of HHO gas to the able to send it through hoses and into the engine's combustion chamber. Furthermore, some machining is need for the vessel. Holes are drilled on the bottom of the vessel to allow for screws, which are welded to the each of the tubes to come out from it. This is done to connect the cables running the current to the screws sticking out of the vessel.

Prototype system description

The chosen design will be a wet cell system. The stainless steel tubes with a negative charge will be connected to the negative pole of the battery and the positive will be connected to a relay, this will give an on/off control of the system while the car is driven. Moreover, the battery assigned to the cell will not be the same battery of the car. The alternator will be in charge of changing a second battery whose sole purpose is to run the electrolysis process. This is done to avoid the main battery of the car from discharging, impairing the vehicle to run properly. Figure 3, shows a diagram for the secondarybattery.

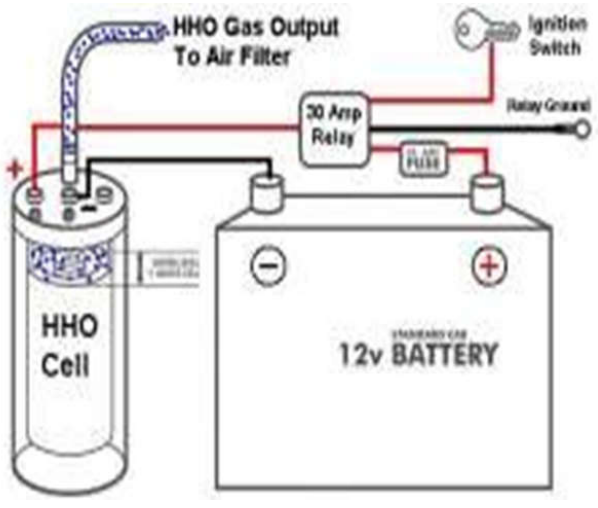

Figure 3. Line Diagram

For the connections, 6 gauge battery cables will be used to reduce electric resistance. To avoid all possible losses the vessel should be placed close to the battery. However, the prototype vessel will be too big to install anywhere on the engine compartment. It will be placed in the trunk of the car. Additionally, an amp meter as well as a fuse will be part of the system. This will help monitor the amount of current drained from the vessel, which is a safety precaution as well. All connections areshown in detail in Figure 4.

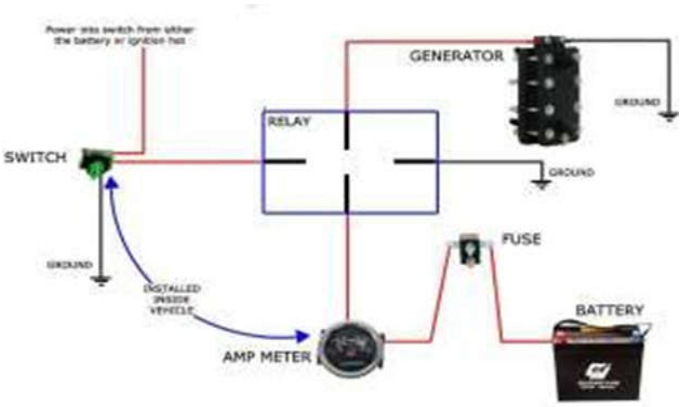

Figure 4. Circuit System Diagram

Ideally, a reservoir tank will be implemented to maintain the level of water required inside the vessel. This will be done automatically with a pump connected to the tank that's regulated by a level sensor placed inside the vessel. As water is turned into gas, new cooler water will enter the vessel. However, due to space and budget constrictions, this was not done. Instead, the vessel has to be filled manually every time the water level is too low. In the case the HHO gas will go into the engine through the air intake, the output gas of the generator cannot be connected directly to the air intake manifold of the car. For safety reasons is important to use an apparatus called "bubbler" between the HHO generator and the intake of the car as shown in the figure below. The bubbler is closed container full of water that will help us avoid any condensed leftover liquid to get into the engine, as well as any back fire from the engine to enter our generator, this could cause an explosion

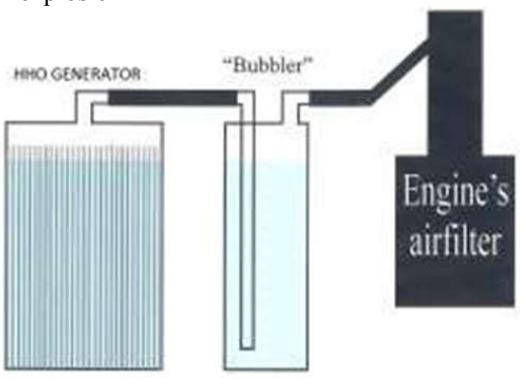

Figure 5. Bubbler Diagram

Plan for testing prototype

The intension of this thesis is to have the HHO generator power the vehicle's engine solely on hydrogen gas and not on fuel. The goal is to build up enough pressure on our vessel so that enough hydrogen can be sent to the fuel injectors and eventually shut off the fuel lines. The alternator will have to

supply enough charge to recharge two batteries. One is the main battery for the car's usual electric tasks, while the other one is used solely to send current to the HHO generator. If this is achieved, then there is no real need to make tests for gas millage since the car will run pretty much solely on water. That would be enough prove that our design works properly. If the engine runs without the need of fuel, this would be a big breakthrough for the team and the automotive industry. However, if the current needed to make enough HHO gas is greater than the current the alternator can produce, then the generator will not be self- sufficient. If this is the case, the generator will be used as a performance enhancer for the engine. The HHO gas will most likely be introduced into the air intake of the vehicle. Now, there would have to be a series of test done to prove that the generator is actually improving gas millage. The test will provide additional proof of the generator's performance. The car will run with a full tank without the operational generator and will be driven normally. The amount of miles traveled will be recorded. Once a certain amount of miles have been driven, it will be filled again and the car will be driven under the same circumstances, this time, with the generator on. Once the same amount of miles

Testing for gas mileage

The following series of steps were done in order to test for improvement of gas mileage. For both the control runs and the experimental runs, some aspects that affect gas mileage are kept constant. These are:

- A/C temperature.
- All windows must be completely closed.
- Tire pressure.
- Weight of the car (only the driver is in the car).
- Driver will try to be consistent with acceleration and rpms at cruise speed.

Control run

1. Fill the fuel tank with 87 octanes until the pump stops by itself.
2. By checking the odometer, drive around 50 miles combined highway and city.
3. Once ~50 miles have been recorded, the fuel tank is refilled at the samegas station.
4. Record the gallons it took for the gas tank to be filled up again.
5. Find gas mileage by dividing miles driven by the gallons consumed.
6. Repeat steps 1 through 5, five times to account for uncontrollable factors, like road conditions and ambient temperature.

Experimental Run:

1. Repeat steps 1 through 6 on the control run with the HHO generator on, while keeping the current (amps) for the electrolysis constant.

Delivery system

One of the alternatives of this generator was to use the HHO gas produced to run the car without the need of fuel. Unfortunately, this ambitious attempt to solve one of society's biggest problems was not successful. The idea was to send the HHO gas through the injectors. But, the fuel injectors of the car were not suitable to handle the gas. Moreover, the problem was due to car's ECU. On average, they are programmed to operate at an air-fuel volume ratio of 14:1. However, as described in Part 4 of this report, for an engine to operate with hydrogen there needs to be an air-H_2 volume ratio of 2.4:1. In terms of percentage, 29.6% of the mixture has to be pure hydrogen gas. The ECU and the injectors are not designed for such a ratio. Furthermore, the car chosen to implement the prototype generator is a *2003 Chevy Malibu*, which has an alternator that generates a current of 105amps. For safety and quality reasons, alternators are designed to operate at 30% to 40% of its maximum output continuously. This means that almost all of its output would go to power the HHO generator and not to charge the car's main battery. Without the use of gasoline, the amount of energy coming from the generator is not enough to power the car, turn the alternator, charge the battery, and power the generator itself again. It's a dead end, not a stable cycle. Since the first delivery system failed, it was decided to use the gas as an additive to the air and gasoline mixture in the combustion chamber. This was done in a very simple way. The hose carrying the gas from the generator was connected to an orifice in the air intake of the car. The HHO gas combines with air and is then sucked into the combustion chamber where it is mixed with gasoline and sparked to make the explosion that moves the piston down and ultimately rotates the crankshaft. Such explosion is said to be more powerful and cleaner. To ensure that the right mixture of air, HHO gas, and gasoline are happening, a pulse modulator was adapted to the car's ECU. This allows for a well-balanced mixture and ensures the car's efficiency. Since hydrogen gas is now a part of the combustion, there is less need for gasoline. Further details of the fuel consumption are explainednext.

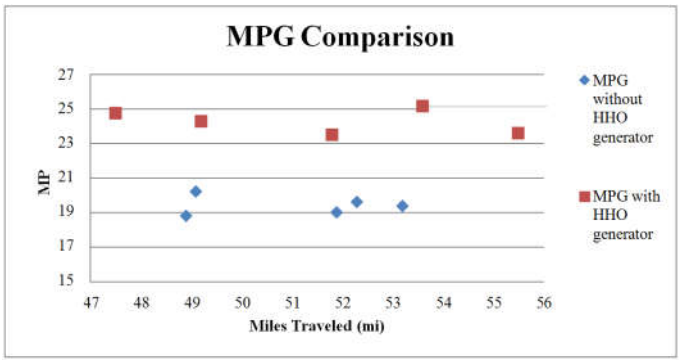

Chart 1. MPG Comparison with and without HHO

It was concluded that the car experienced an increase of 4.86 miles per gallon combined (highway and city), going from 19.42 to 24.27 mpg. This is a 25% decrease of fuel consumption, which is an astonishing amount. This shows proof that HHO gas, as an additive to a car, does work and saves the consumer money on their gas expenditure.

Payoff period

Knowing the total cost of the generator, including parts, machining, and installation, a prediction can be made based on the 25% increase in miles per gallon. Based on data from 2011, the US Department of Transportation states that the average American 13,475 miles per year. For a person to drive a car like the one tested on this project with a generator such as the one described here, taking the cost of fuel to be an average of

$3.50 and based on a fuel consumption reduction of 25%, the amount of savings is as follows:

Advantages

- No harmful particulates' emission
- Improved engine power and performance
- Increased fuel efficiency by 40-50%
- Eliminate carbon deposits
- Reduced heat in combustion chamber
- Flawless engine operation
- Enhanced Engine components' life
- Less expense on maintenance

Disadvantages

• Less popular and limited availability
• High Fuel cell changing cost
• Frequent maintenance
• Adequate engine lubrication
• Engine breakdown owing to low quality equipment fitting

Appendices

The following are photographs of manufacturing of the actual prototype.

Figure 6. Cutting Steel tube

Figure 7. Assemble component

Conclusion

There is a lot of skepticism about HHO generators for vehicles found online. Our final thesis gives valid evidence that, in fact, they do work. It was determined that in order to supplement fuel consumption with hydrogen gas completely, many modifications need to be made to the fuel system of the car, that were out of our reach. Even if these were accomplished, the amount of energy needed for the car to run as well as to power the generator is not enough without the energy coming from the fuel. The hydrogen cell produced oxygen and hydrogen from water through electrolysis. Minimization the cost was done by using wildly available materials. Once Plan A was not successful, Plan B was implemented. From the results of the experiment it can be concluded that having an HHO generator such as this one, will improve gas mileage. The findings of this senior thesis benefit the environment and society. Since implementing the hydrogen generator will produce less carbon dioxide to the atmosphere, as well as, less consumption in gas. There for it will reduce greenhouse gasses. Hence, less effect on global warming on the long run. Moreover, since implementing a hydrogen generator will provide more fuel efficiency, it will save money for people who will use our product. It is hard to tell if the generator will continue to be as efficient in the long run, because we couldn't take into account alternator wear or battery productivity. However with regular checkups these factors can be taken care of. The process to design and manufacture was a little tedious, as we needed to do research on the different types of electrolysis and HHO generators. Many times we encountered people claiming that such generators are not efficient and that, in fact, they are a myth and don't work. This was kind of discouraging sometimes. But we kept working through with the intention of showing proof of their effectiveness. We were very pleased when we acquired the results showing an improvement in gas mileage. As engineers, we felt accomplished to know that such device can help alleviate some of society's biggest issues.

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