Enhancement of Internal Combustion Engines Performance Using Solar HHO-System: Preliminary Conceptual Results

Yazid Amrani, Matheus Montarroyos
Raul Martin Martin, Gaetan Gilbrice Tchewa
Department of Mechanical Engineering
West Virginia University Institute of Technology
Montgomery, WV 25136
Undergraduate Mechanical Engineering Students
Email: yaamrani@mix.wvu.edu, mattmontarroyos@gmail.com
raulmartinv@gmail.com, gatchewa@mix.wvu.edu

Farshid Zabihian
Department of Mechanical Engineering
West Virginia University Institute of Technology
Montgomery, WV 25136
Assistant Professor
Farshid.Zabihian@mail.wvu.edu

Abstract

This report recommends the use of a newly designed solar-oxyhydrogen system that will improve several aspects of an automobile and the environment. Oxyhydrogen, mostly known as HHO, is a mixture of hydrogen and oxygen gases that can be produced through water electrolysis. The recommended design of this system includes the use of solar power in the form of flexible solar panels that have the capability of converting photovoltaic rays from the sun into electrical power. For this design, the flexible solar panels will be placed on the roof of vehicle and this would be the source of the electrical power needed by a dry cell to function and therefore generate HHO. The HHO produced will be injected directly into the engine. The implementation of this design will increase any vehicles efficiency and could even probably be able to compete against hybrid cars. This project explores the conceptual development of this system which in the future, will be built and tested for its reliability by the group members.

Introduction

Every year major companies such as Toyota, Ford, and Chevrolet invest millions of dollars trying to increase the efficiency of their motor vehicles. According to the U.S. department of energy only 14 to 30% of the gasoline is actually converted into motion, the remaining 86 to 70% are lost in friction, wind and rolling resistance, braking and other irreversibilities [1]. On the other hand, a hybrid car (electricity and gasoline) has almost 0 idle losses and can convert 5 to 9% on regenerative braking, making this type of car much more efficient (25-40%) [2].

Therefore, when people are going to choose their car, picking a hybrid over a regular car would be the obvious choice given their advantages. However, hybrid cars are much more expensive than the regular ones. With our project, we intend to give the regular cars a better chance to compete against the hybrid cars. We would increase their fuel efficiency, which would reduce the annual cost with fuel, and make the exhaust emissions cleaner. The annual fuel cost projection of the US Department of Energy assumes a car travels 15,000 miles and that the price for a gallon of unleaded gasoline is $2.64/gallon [3]. So we can estimate that the expenses with fuel, per year, of a person with a car that does 20 miles per gallon (mpg) is $1,980. If we could increase the mpg in a least 10%, it would reduce the annual expense with fuel to $1800.

Moreover, another motivation for this project was the amount of pollution that a car produces. According to the union of concerned scientists, in 2013 the transportation sector contributed for more than a half of the carbon monoxide and nitrogen oxides, and almost a quarter of the hydrocarbons emitted into our air [4]. This is really harmful for people's health and for the environment. One of the mains key points of our design is to provide a better and cleaner combustion

This project will propose the design of a system that injects HHO directly to the engine and when integrated to a car will be capable of optimizing its fuel efficiency. Besides that, we expect to achieve a cleaner exhauster's emissions, having in mind that the combustion product of HHO is mostly water.

Nowadays there is not a lot of equipment that when attached to a car will increase gas mileage. The only experimental pieces of equipment that claims to increase efficiency are the pressurized gas tank and the HHO injection. Pressurizing the gas tank is based on Henry's law, which states that the solubility of a gas increases according to the pressure [5]. This equipment uses a small compressor to compress air inside the gas tank, dissolving mainly oxygen and nitrogen into the liquid (Fuel). When this fuel with dissolved air goes to the combustion chamber, it produces a faster combustion process and more through. The other method is injecting HHO (oxyhydrogen) inside the combustion chamber. This mixture of hydrogen gas and oxygen should increase the thermal efficiency of the burning process, producing a cleaner and cooler combustion. The final result from injecting this mixture into the cylinders is a greater gas mileage.

The purpose of this project is to propose the design of a HHO injection system that might actually increase the thermal and mechanical efficiency of a car, resulting on a gas mileage increase and cleaner emissions. The experimental analysis to verify if the design actually works and to measure how well it can perform will not be made due to lack of material and equipment. For future reference, to verify the performance of the design a small engine would be needed as well as enough material and budget to buy the components and build the system.

The first step for the project is to make further research on the fuel that will be used, the HHO. This gas is simply a 2:1 mixture of Hydrogen and Oxygen. It has an autoignition of 570 °C (1065 °F). When ignited the gas mixture is converted to water vapor and energy, and it is estimated that 241.8 J of energy is released for every mole of H_2. One of the most important qualities of this gas is that when mixed with another inert gas (gases that do not undergo any chemical reaction), the heat should spread out through the matter having a lower temperature [6].

There are a variety of ways to produce Hydrogen, however the only way to produce HHO nowadays is the electrolysis of water. This process consists on passing a direct current (DC) through a substance in order to separate the molecules of the substance. In the case of water, the current goes through it and separates the atoms of Hydrogen and Oxygen, forming a gas called HHO (oxyhydrogen).

Some companies such as Honda and BMW have already manufactured some cars that run fully on hydrogen. The BMW Hydrogen 7 [7] can run fully on hydrogen or gasoline. The engine was modified in order to work with both fuels. While running on hydrogen it produces almost no pollutants. However, the biggest issue of these cars is the fact that they have a cylinder that stores hydrogen at high pressure. This type of storage brings up two issues. First of all, during an accident the tank can explode causing a lot of destruction and even death; making this not the safest design. Second, the tank makes the vehicle much heavier, consuming more fuel.

The design we propose does not have a cylinder or any compartment that stores hydrogen. Our system can be classified as production on demand, meaning that all the hydrogen generated won't be stored anywhere, the produced hydrogen will go straight into the engine when needed. When the engine is turned off the dry cell will shut down and hydrogen won't be generated. Using this method we will be able to have lighter and safer hydrogen enhanced cars.

Our design is composed by roughly 4 steps: energy sources, electrical system, dry cell, injection method.

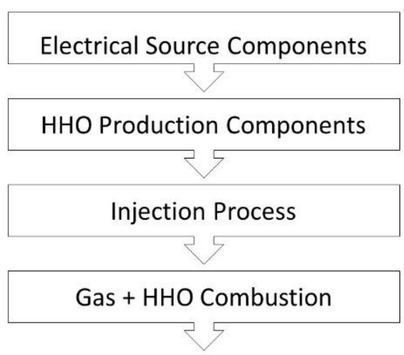

Figure 1: HHO Production Steps

Figure 1 shows how the HHO will be produced and inserted into the engine. First electricity will provided from solar panels and stored in a battery. When needed, the battery will send electricity to the dry cell so it can make the electrolysis in the water generating HHO gas. This gas would then go through a bubbler and some other components so the injection into the engine can be done safely.

In order to power the dry cell electricity is needed. There a lot of ways to harness electricity, some of them more efficient than the others. In a car the alternator is a component that converts one part of the mechanical energy produced by the engine mechanical energy to electricity. This electricity is used to constantly recharge the battery and also to power some of the electrical components of the car, such as headlights and some internal components.

Some systems that already exists in the market uses the alternator of the car as an electrical energy source. The electricity input of the dry cell is attached directly into the alternator. The creators of this method claims that you should have an increase on the gas mileage of the car when the entire system is fully operational and getting electricity from the alternator. However, this statement goes against the 1st law of thermodynamics. If the system is hooked up to the alternator or battery no additional work is being added to the system. The dry cell system would be using the mechanical energy from the car and putting it back to the engine. Since this is not an ideal cycle, there are a lot of irreversibilities. So neither the dry cell nor the alternator has 100% efficiency, thus work would be lost during the HHO production process with no gain in thermal or mechanical efficiency.

In order to solve this issue and have an actual gain in gas mileage it was decided that renewable sources of energy would be used to provide electricity to feed the dry cell. For now, 3 solar panels will be placed on the roof of the car. We decided to place them on this location because that's where the solar incidence is more constant and more intense.

The chosen solar panel, Figure 2, for the design, was the GP-FLEX 200 from Go Power [8]. We chose this solar panel because they are very durable and can endure bending to be fit on the curved rooftop of several cars. According to the manufacturer, every panel is able to bend up to 30 degrees with respect to the original axis. Figure 3 is depicting the bending capabilities of the solar panel, and Table 1 lists its specifications.

Figure 2: GP-FLEX 200 Solar Panel [8]

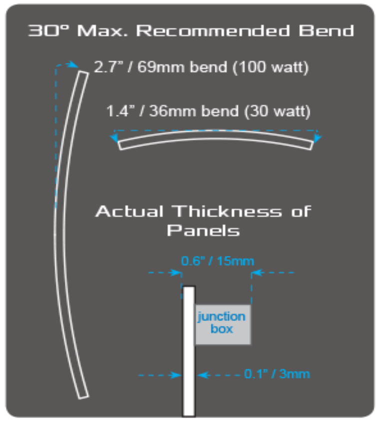

Figure 3: Bending capabilities of GP-FLEX 200 [8]

Table 1: GP-FLEX 200 Solar Panel Specifications [8]

Cell Type	Monocrystalline
Solar Panel Output Power	100 W
Solar Controller	30 A, PWM
Output Power warranty	10 years
Maximum power current	5.62 A
Maximum power voltage	17.8 V
Open circuit voltage (Voc)	20.8 V
Short circuit current (Isc)	6.01 A
Module Efficiency	19.99%
Maximum System Voltage	60 VDC
Maximum power tolerance	+/- 5%
Dimensions (cm)	106 x 54 x 0.3
Surface Area	5724 cm^2
Weight	1.35 kg

In the United States the most sold cars every year happen to be the mid-size cars [9], which are also known as intermediate cars. Since this is the case, we chose to implement these solar panels on the rooftop of this kind of car. According to USA Today, the car that has been top-selling for the past two years is Toyota Corolla [10], which happens to be a midsize car.

According to the dimensions of the Toyota Corolla shown on Figure 4 [11] we can conclude that the rooftop could hold up to three solar panels.

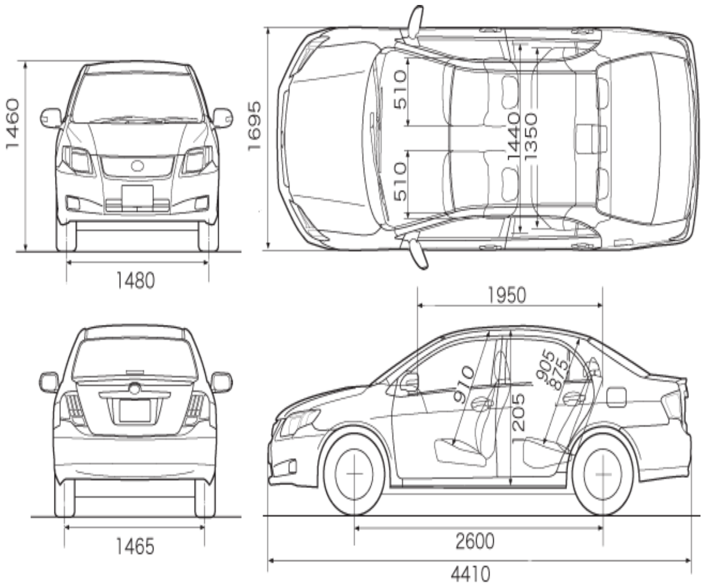

Figure 4: Toyota Corolla Blueprint [11]

Since the schematic on Figure 4 is drawn to scale, we were able to conclude that surface area of the rooftop was about 16178.4 cm^2. One of the GP-FLEX 200 solar panels' surface area is 5724 cm^2. This means that about 3 solar panels of this kind could be placed above the rooftop of a Toyota Corolla. Figure 5 shows the same car from Figure 4 but now with the solar panels on top.

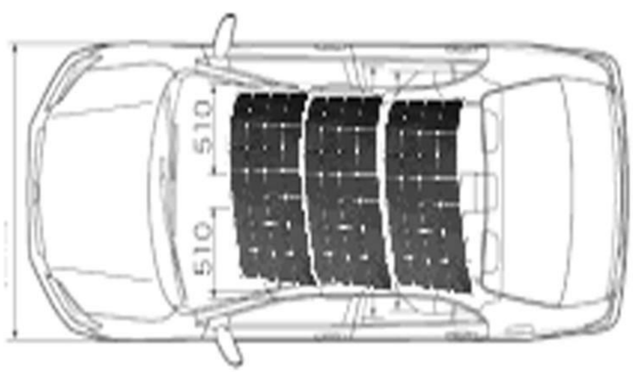

Figure 5: Rooftop with 3 GP-FLEX 200 Panels

After deciding the type of solar panel and where it is going to be placed, we had to develop a system that would be able to store the electricity generated by the panels. The electrical components of this system are the solar panel, the battery and the charge controller.

The solar panel will generate electricity and will constantly recharge a battery placed in the car (different from the one a car uses to start the engine), a solar controller will then regulate the amount of current and voltage that is transferred to the battery and to the dry cell, not letting it overcharge or damage the battery. The schematics for the electrical components are shown in the Figure 6.

The InnoGear® Solar Panel Charge Controller [12] plays an important role on the electrical system. It is responsible for controlling the charge and discharge process in the battery. We chose this model because it is capable of directing the electricity to the battery or straight to the dry cell, depending on the battery status and how much power the solar panels are providing to the system. This system is shown in Figure 7, the specifications for the charge controller can be found on Table 2, and the specifications for the battery can also be found on Table 3.

Figure 6: Electrical Components [12]

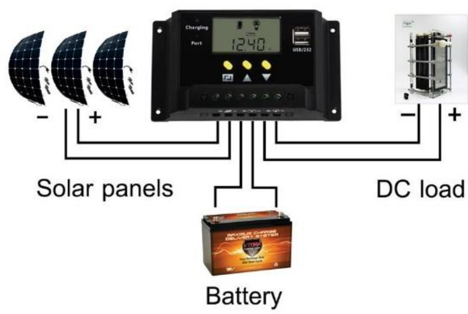

Figure 7: Charge Controller configuration [12]

Table 2: InnoGear® Solar Panel Charge Controller Specifications [12]

Maximum voltage of PV:	30A
Maximum discharge current:	30A
Maximum output voltage:	12V/24V
Maximum output power:	360W/720W
Size:	14.5 x 8.0 x 3.0 cm
System voltage of PV:	40V
Charge way:	3statePMW Charge
Temperature compensation:	YES
Compatible battery:	lead-acid cell

Table 3: SLR100 AGM Solar Battery Specifications [12]

Nominal Voltage:	12V
20Hr Capacity:	100AH
RC:	220 min
Energy:	1.350 kWh
Terminal Posts	8mm (included)
Dimensions:	12.1"w x 6.7"d x 8.2"h
Weight:	68lb

Charging Current:	7A-30A
Charging Voltage:	14.4V-14.9V
Float Voltage:	13.5V-13.8V
Solar Panel (Charging):	150W-400W
Charge Controller:	20A-UP

Electricity Produced per day=Solar Panel Output Power * Area of panel * efficiency of the panel * average hours of sun per day.

Assuming that a car is exposed to about three hours of direct sunlight in a day, then each panel will be able to produce a daily 0.1029 kWh of electricity. A sample calculation is as follows:

Output Electricity: 100W*0.5724m^2*0.199*3 hours per day = 0.034327 kWh. Since it was calculated that a maximum of 3 solar panels could be placed on the roof of a mid-size car then that value obtained for maximum output electricity would be multiplied by three and thus yielding a total final electrical output of 0.1029 kWh per day. The SLR100 AGM Solar Battery has the capability of storing 1.350 kWh which is more than what is need, thus being a successful choice.

Currently there are only some equipment that use the electrolysis of water to produce HHO. The most common ones are the wet cell and the dry cell. In the wet cell, the electrodes are submerged in water; conversely for the dry cell the electrodes are fixed and water flows between the plates. If we compare between both of these cells, the dry cell is more efficient and can produce more HHO than the wet cell and that is why the dry cell was selected for this design as a source for HHO production [11].

There's a specific amount of electrical current that needs to go through the water. According to Faraday's Law [13], the minimum amount of voltage for the best efficiency of the dry cell is 1.24 volts. If the voltage is greater than that value the energy will be lost to heat. However, this number was based on battery acid, so it is impractical to use it with water.

The better the flow of current the better the separation of water will be. Water cannot conduct electricity itself, that's why electrolytes are needed, so it can help with the conduction of electricity.

Some electrolytes aren't as good as others. The perfect electrolyte is the one that helps to conduct current, but does not participate on the chemical equation. It has been proved that KOH and NaOH are really stable and are not consumed during the electrolysis. [14] Some other substances will be consumed during the process and will accumulate on the electrodes making the whole process less efficient.

Another important topic that needs to be taking into consideration when producing HHO is the maximum current density. It is really important so energy is not lost in heat. All the electrons that flow within water produces heat, and our goal is to reduce as much as possible the losses in heat [15].

Those were important concerns that were taken into account when choosing the right dry cell and that is why the following dry cell was selected. This is the unit in the system that will be constantly generating HHO. It is a newly developed 21 plate dry cell. This dry cell can operate at 12 V and has a total current of 3 Amps. Using the software on the hho4free website, the calculated input power was 36 Watts, or 0.036 kW [11]. This dry cell has the capability of producing 5 liters per minute of HHO, which might be enough to improve the efficiency of an automobile. This dry cell requires a relatively high power to function; however, our solar system is able to generate 0.1029 kWh and therefore it could function without any problem.

The IHHOI (International HHO Institute) have made some experiments and came up with a chart that relates engine size liters, Amps, and LPM (liters per minute). According to that chart [16], one fourth liter per minute of HHO for each liter of engine size is required to increase an automobiles mileage. For a 2.0 liter Toyota Corolla 0.5 liters per minute of HHO is needed. This means that theoretically the dry cell will be capable of providing enough HHO for the engine. Since the engine in the lab could not be tested, then this report does not include experimental results that show amount of increase in efficiency when the desired amount of HHO is added into the engine.

HHO is sometimes known as a detonating gas. This is because HHO has the ability to burn as soon as it is subjected to an ignition. According to a report from BMW [7], hydrogen alone is not explosive, however when it is mixed with oxygen and other gases and when it is given some sort of small ignition energy. There is the possibility of an ignition to happen [7].

HHO will be produced by the dry cell and it will be sent to the engine intake through a fuse. Autoignition of HHO gas occurs around 570^{o}C which is about 1065^{o}F and the minimum energy that should be provided to ignite the mixture is about 20 micro joules. Oxyhydrogen has the ability to burn when it is between 4% to 94% hydrogen in terms of volume. After the oxyhydrogen undergoes ignition, then it becomes water vapor and as a result energy is released [13].

Conclusion

Oxyhydrogen, mostly known as HHO, is a mixture of hydrogen and oxygen gases that can be produced through water electrolysis. Electrolysis is a process, which uses a DC electric current to separate the water molecules and thus producing HHO. The current systems that are integrated into vehicles range from implementation of a hydrogen tank that is refilled just like an ordinary fuel tank or the implementation of a dry cell, which is a device that generates HHO. The first is a hazardous design because if a vehicle ever happens to be involved in an accident. The dry cell in the second design is powered by electricity coming from a vehicle's alternator which provides power to a car's electrical system when its engine is running. This means that the car should consume more fuel to produce sufficient electricity to power the dry cell and this means that the vehicle would consume more fuel. The solar cell-power system proposed and designed in this paper will have neither of these problems and can improve the efficiency, reduce fuel consumption, and decrease environmental impacts of vehicles.

Bibliography

[1] https://www.fueleconomy.gov/feg/atv.shtml
[2] https://www.fueleconomy.gov/feg/atv-hev.shtml
[3] http://info.ornl.gov/sites/publications/files/Pub37730.pdf

[4] http://www.ucsusa.org/clean_vehicles/why-clean-cars/air-pollution-and-health/cars-trucks-air-pollution.html#.VimNSdaprzI
[5] http://chemwiki.ucdavis.edu/Physical_Chemistry/Physical_Properties_of_Matter/Solutions_and_Mixtures/Ideal_Solutions/Dissolving_Gases_In_Liquids,_Henry's_Law
[6] https://en.wikipedia.org/wiki/Oxyhydrogen
[7] http://www.bmw.com/com/en/insights/technology/efficient_dynamics/phase_2/clean_energy/bmw_hydrogen_7.html
https://en.wikipedia.org/wiki/BMW_Hydrogen_7#cite_note-1
[8] http://gpelectric.com/products/solar-flex-kits-modules
[9] http://www.motortrend.com/news/2012-2013-midsize-sedan-comparison/
[10] http://www.usatoday.com/story/money/cars/2013/04/09/most-popular-car-ford-focus-fiesta-honda-civic-toyota-camry/2066187/
[11] http://www.ogohho.com/goods/detail.do?gid=45
[12] http://solarpanelreviewer.com/innogear-solar-panel-charge-controller-12v-24v-360w-720w-pwm-regulator-monitor-for-street-lighting-system-environment-monitor-garden-auto-system-battery-charging-wifi/
[13] http://www.hho4free.com/configurator/cell_configurator.htm
[14] http://auto-hydrogen.com/what-is-hho/hho-electrolytes-explained
[15] http://www.hho4free.com/current_density.htm
[16] https://www.fuelsaver-mpg.com/how-much-hho-should-i-use?zenid=fb4073d72f07d870b66dece5155c12d9
[17] http://www.volkspage.net/technik/ssp/ssp/SSP_230.pdf