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16. Abstract

The current project is aimed at evaluating a low-cost, aftermarket technology that has the potential to convert the 250+ million, currently-operating fleet of non-hybrid vehicles to pseudo-hybrid vehicles without any major vehicle modifications. Conceptually, the aftermarket add-on pseudo-hybrid system comprises of an Oxy-hydrogen generator (HHO or Brown's Gas), a storage tank, a higher capacity alternator (that may use the same mounting holes), and operational modifications to the alternator and fuel control system (through the Engine Control Unit – ECU). For the proposed project, several electrolysis-based HHO generators were purchased and tested using 12 volt DC power supply. The actual production from the generators was compared to the theoretical quantities estimated by the Faraday's law of electrolysis. The measured HHO production was approximately 64% of the theoretical production. The next phase of the project involved testing the horsepower and torque generated from multiple 4-stoke, air-cooled engines (205-250 cc engine displacement) using an engine testing dynamometer. Each engine was first tested for it baseline horsepower and torque at various engine loads and rpms. The fuel consumption for the unmodified engines was quantified at various loads. The main fuel jet in the carburetor was subsequently changed to a finer jet (which delivers lesser fuel). The horsepower and torque of the modified engine was tested. Results indicated that substituting the gasoline fuel with 13.1% hydrogen (on a BTU basis) resulted in up to 59% fuel savings, without any significant loss in horsepower or torque. However, when the engine testing was repeated with the addition of both hydrogen and oxygen, the engine temperature quickly went up and heated the carburetor and engine components to unsafe temperatures. The excess oxygen in the fuel mixture likely improved the combustion efficiency and elevated the engine temperatures. The last phase of the project involved modification of a 150 CC scooter to accept an oversized alternator to generate the HHO gas during the braking period. Although the scooter was modified to accept a new alternator, final testing was not completed due to technical and safety reasons (explained in the report). Further research has to be done with a larger grant to validate the preliminary fuel savings, evaluate engine emissions with HHO supplementation, and demonstrate the results using a 4-wheeled automobile.

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Easy Add-on Fuel Saver for Non-Hybrid Vehicles

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ABSTRACT

Hybrid passenger vehicles were introduced to the United States in 1999 and several federal and state incentives were offered to customers in the last 16 years. Currently, less than 1.2% of the estimated 250 million registered passenger vehicles in the United States are hybrid vehicles. This figure reflects a very slow acceptance of hybrid technology, which can be primarily attributed to the higher cost of hybrid vehicles when compared to non-hybrid vehicles with similar features and functionality. The current project is aimed at evaluating a low-cost, aftermarket technology that has the potential to convert the 250+ million, currently-operating fleet of non-hybrid vehicles to pseudo-hybrid vehicles without any major vehicle modifications. Conceptually, the aftermarket add-on pseudo-hybrid system comprises of an Oxy-hydrogen generator (HHO or Brown's Gas), a storage tank, a higher capacity alternator (that may use the same mounting holes), and operational modifications to the alternator and fuel control system. For the proposed project, several electrolysis-based HHO generators were purchased and tested using 12 volt DC power supply. The actual production from the generator was compared to the theoretical quantities estimated by the Faraday's law of electrolysis. The measured HHO production was approximately 64% of the theoretical production, which was well within the values reported in literature (52% to 67%). The electrolysis experiments quantified the volume of Brown's gas that can be generated from a heavy duty alternator for a specified braking period.

The next phase of the project involved testing the horsepower and torque generated from multiple 4-stoke, air-cooled engines (205-250 cc engine displacement) using an engine testing dynamometer. Each engine was first tested for it baseline horsepower and torque at various engine loads and rpms. The fuel consumption for the unmodified engines was also quantified. The main fuel jet in the carburetor was later changed to a finer jet (which delivers lesser fuel). The BTUs lost due to reduced quantity of fuel entering the engine (due to finer jet) was computed. The engine air intake was modified and an equivalent amount (BTUs) of hydrogen was mixed with the incoming air. The horsepower and torque of the modified engine was tested. Results indicated that substituting the fuel with 13.1% hydrogen (on a BTU basis) resulted in up to 59% fuel savings, without any significant loss in horsepower or torque. However, when the engine testing was repeated with both hydrogen and oxygen, the engine temperature quickly went up and heated the carburetor to unsafe temperatures. The excess oxygen in the fuel mixture improved the combustion efficiency and elevated the engine temperatures. The gas supplementation experiments indicated significant possible fuel savings and gave better insights into the limitations of HHO supplementation. As HHO gas is anticipated to be supplemented only during the braking period, the increase in engine temperatures may not be a major concern for the real-world water-cooled engine. However, the engine emissions and potential water production within the engine chamber have to be further researched. The last phase of the project involved modification of a 150 CC scooter to accept an oversized alternator to generate the HHO gas during the braking period.

Although the scooter was modified to accept a new alternator, final testing was not completed due to technical and safety reasons (explained in the report). Further research has to be done with a larger grant to validate the preliminary fuel savings, evaluate engine emissions with HHO supplementation, and demonstrate the results using a 4-wheeled automobile.

ACKNOWLEDGMENTS

The Principal Investigator wishes to acknowledge the assistance and help offered by Tom McClure, the shop-in charge in the Biological and Agricultural Engineering. His assistance on making engine mounts for the dynamometer testing, modification of carburetor intakes, and machining parts for the crankshaft of the 150 CC scooter to accept an external alternator is greatly appreciated.

IMPLEMENTATION STATEMENT

The funds from the LTRC's seed grant facilitated procurement of key data for advancing the proposed aftermarket hybrid technology. The initial electrolysis experiments gave clearer insights on the quantities of hydrogen and oxygen that can be generated from an electrolytic cell during the braking period as a function of electrical wattage passing through the cell. The deviation of the actual gas production from the theoretical gas production (estimated from Faraday's law of electrolysis) was quantified. The engine dynamometer experiments on un-modified and modified air-cooled gasoline engines supported the proposition that lower amounts of gasoline is needed for engines that are supplemented with hydrogen gas. On a more positive note, results also indicated that substituting the fuel with 13.1% hydrogen (on a BTU basis) resulted in up to 59% fuel savings without any significant loss in horsepower or torque. However, it is not clear how a 13.1% substitution by hydrogen can result in up to 59% gasoline savings. It is very likely that hydrogen assisted in improved combustion properties of the mixture. Before drawing any conclusions of synergistic benefits due to hydrogen supplementation, it is important to repeat the experiments with multiple engines and confirm the current findings. Furthermore, it is important to test the engine emissions to ensure that the engine is not running too lean (and releasing pollutants). Another important observation from this seed research is related to the increase in engine temperature when both hydrogen and oxygen were added to the engine compartment. In summary, research findings from the LTRC's seed grant validated the overall concepts behind the aftermarket hybrid technology that can be retrofitted to a non-hybrid vehicle with minor alternations to the vehicle. The results and key finding from the current research will be fully leveraged in seeking a larger grant to further validate and demonstrate the aftermarket hybrid technology on a full-sized automobile.

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INTRODUCTION

The United States is home to the largest passenger vehicle market of any country in the world.[i, ii] At the end of 2011, there were an estimated 253.1 million registered passenger vehicles in the United States.[i] Despite increased awareness of hybrid vehicles since their inception in 1999 and governmental incentives, the United States had only around 2.5 million hybrid passenger vehicles on the road by the end of 2012[iii]. Therefore, the acceptance of hybrids can be considered as "slow", primarily due to the high costs associated with the hybrid technology, which traditionally involves an additional electrical motor, regenerative braking components, and expensive batteries. The current project is aimed at developing a low-cost, aftermarket technology that can convert the 250+ million, currently-operating fleet of non-hybrid vehicles to pseudo-hybrid vehicles without any major vehicle modifications. Conceptually, the aftermarket add-on pseudo-hybrid system comprises of an Oxy-hydrogen generator (HHO or Brown's Gas), a storage tank, a higher capacity alternator (that uses the same mounting holes), and operational modifications to the alternator and fuel control system (through the Engine Control Unit – ECU).

In a typical automobile, the alternator regulator lowers the output of the alternator to a fraction of the full capacity to prevent overcharging of the batteries and to avoid excessive voltages. The first operational modification of the proposed aftermarket hybrid system will involve modifying the alternator regulator to request a full power output (say 100% as opposed to 10%) during braking. The excess energy that is generated during the braking period (say during 10-20 seconds) is used to produce massive quantities of hydrogen and oxygen using an electrolytic cell. The call for increased power production during the braking period lowers the momentum of the vehicle by putting additional alternator load on the engine, thereby lowering the rpm of the engine and simultaneously assisting in slowing the vehicle. The two gases (hydrogen and oxygen, also known as Brown's gas or HHO) generated at the two electrodes are collected in a separate storage chamber. The collected gas, which has fairly high energy content (66,000 BTU/lb) is fed into the air-intake during the vehicle acceleration (say the first 10-20 seconds). When ignited, HHO generates 241.8 KJ of energy (LHV) for every mole of H_2 burned[iv]. With this supplemental energy input, the high fuel needs of the engine during the initial acceleration can be lowered proportionally, thereby, partially recovering the energy that is typically lost due to braking. Apart from potential fuel savings, the HHO blending has several other environmental and economic merits. The blending of HHO with fossil fuel will result in a more complete combustion of the fuel-air mix[v]. A more complete combustion directly relates to lower exhaust emissions such as hydrocarbons, nitrogen oxides, and carbon monoxide[vi]. Furthermore, the ultra-fast flame velocity of hydrogen (10x faster compared to gasoline) was reported to generate better acceleration and torque from the engine[vii]. Yet another notable advantage of blending HHO with gasoline is the increase in octane rating of the gasoline fuel.

Due to limited time and funding that is available from this seed grant, the overall pseudo-hybrid concept could not be demonstrated on a full-sized passenger vehicle (car or truck). It is important to note that the emphasis of this research was be to validate the underlying concepts using laboratory experiments, engine dynamometer testing, and fuel consumption tests on unmodified and modified engines.

OBJECTIVES

The ultimate goal of the proposed research was to explore the overall viability of an add-on fuel saver for non-hybrid passenger vehicles. The specific objectives that were addressed for this project include:

1) Quantify the HHO gas generated from using the excess power in a electrolytic cell and compare the gas production with theoretical values based on Faraday's laws.

2) Modify the engine carburetor and incorporate features that will lean the gasoline fuel intake when HHO gas is fed to the air intake

3) Evaluate the engine performance and fuel consumption of a separate 4-stroke gasoline engine with varying air/fuel/HHO mixtures using an engine testing dynamometer

4) Modify the power generation and alternator regulator circuitry of a 150 CC gasoline scooter to generate maximum wattage during the time of braking.

SCOPE

Due to limited funding and resources, the emphasis of the current project was to evaluate the underlying concepts as identified in the objectives. Specifically, the project scope is limited to: 1) verifying the quantities of brown gas generation based on lab-scale electrolysis experiments and comparing to theoretical production, 2) testing of unmodified gasoline engines (6.5 – 10 HP) using an engine-testing dynamometer to establish baseline horsepower, torque, and fuel consumption, 3) modifying the engines to draw lesser gasoline fuel and with provisions to take in hydrogen and hydrogen-oxygen gas mixtures, 4) evaluate the performance and fuel consumption of the modified engines, and 5) to test the concept of regenerative braking on a 150 CC scooter using an externally mounted alternator. However, demonstrating the overall concepts of "aftermarket hybrid" on a non-hybrid passenger vehicle is not considered to be within the scope of this project. Based on the findings and results from the current study, the PI wishes to seek a larger grant to validate and demonstrate the "aftermarket hybrid" using a passenger vehicle.

METHODOLOGY

Electrolysis and Oxy-Hydrogen Generation

Water electrolysis (hydrolysis) is a well-studied and developed technology for the generation of hydrogen gas from liquid water. During hydrolysis, electricity is used to split a H_2O molecule into H_2 and O_2. The minimum necessary voltage required for hydrolysis defined as $E^{O}_{Cell} = -\Delta G^{O}/(nF)$, where E^{O}_{Cell} is the voltage, ΔG^{O} is the change in Gibbs free energy, n is the number of electrons transferred in the reaction, and F is the Faraday constant (96485 C/mol). In the case of electrolysis of water in an open system, this value comes out to 1.23 V. In practice, a minimum voltage of 1.48 V must be applied in order to be thermoneutral; below 1.48 V the cell operates endothermically, and above 1.48 V the cell is exothermic.[viii] The quantity of gas produced through hydrolysis is defined by Faraday's law of electrolysis: $m = (It/F)*(M/z)$, where m is the mass of gas produced, I is the cell current, t is time, F is the Faraday constant, M is the molar mass of the substance and z is the number of electrons transferred per ion.[ix] In practice for hydrolysis, the only variable that controls the rate of gas production is the cell current, I. Therefore, a higher current leads to a higher volume of hydrogen and oxygen produced. However, it is important to note that experimental gas production will be significantly lower than the theoretical quantities. For this study, an experimental system was set up to test electrolysis using an OGO electrolysis cell (www.ogohho.com). A power supply was used to apply 12 V and 4 A to the cell, and the rate of gas production was measured by timing the rate of water displacement by the gas in an inverted graduated cylinder. A photo of the electrolysis setup is shown in Figure 1.

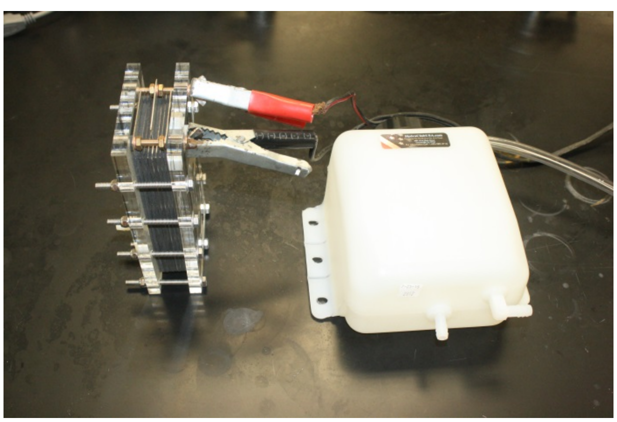
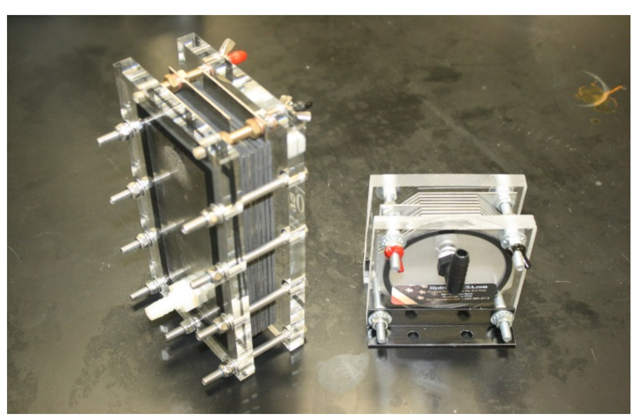


Figure 1: *Electrolytic cells were used to quantify the volume of oxy-hydrogen produced. Based on this data, the volume of gas generated for a given braking period and a specified alternator can be computed.*



Carburetor Leaning and Gas Supplementation

Oxy-hydrogen supplementation alone is not anticipated to result in fuel savings. Gas supplementation together with reduction in the amount of gasoline fed to the engine is the key requirement for the proposed aftermarket hybrid system. Traditionally, a gasoline engine is fed a fuel-air mixture at a stoichiometric air to fuel (gasoline) ratio of 14.67:1. The carburetor of a 205 cc displacement, Briggs and Stratton engine was modified and retrofitted with a finer fuel jet. Engine was originally fitted by the manufacturer with a #81 jet. Several finer jets were installed (#67, #71, #74, #77) and the modified engines were tested on an engine testing dynamometer (HUFF Technologies, Model: Small Engine Dynamometer). Jets that were too fine did not sustain satisfactory engine operation. However, the jets that would deliver a similar horsepower with torque with supplemental hydrogen injector (supplying 10-15% of BTUs) were identified. The best jet (#77) was used for all modified engine runs.

For facilitating gas injection, the intake housing and filter assembly was removed and fitted with a metal plate that is welded to a ¾" (NPT male) metal pipe. Depending on the gas or gases that have to be injected, pipe adapters and "tee" (or "Y") were added to the ¾" metal pipe. A photograph of the modified intake is shown in Figure 2. Metered quantities of hydrogen and oxygen stored in compressed gas cylinders were supplied to the modified engine.

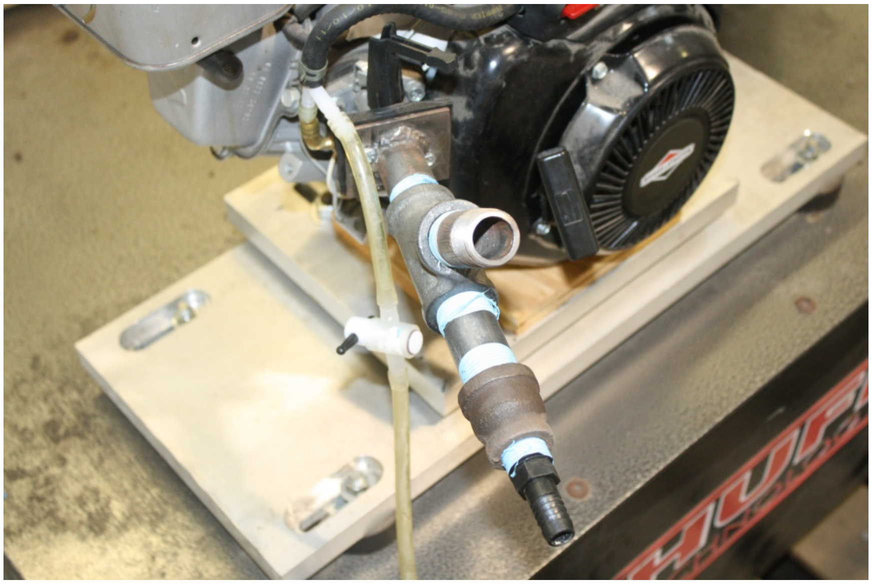


Figure 2: *The air filter housing and air intake of the Briggs and Stratton engine was modified to accept metered quantities of hydrogen and oxygen*

Dynamometer Engine Testing

Both unmodified and modified engines were tested on the Huff Technologies Engine Dynamometer (Figure 3). Custom engine mounts were made for testing various air-cooled gasoline engines (205 CC and 250 CC displacement, 4-stroke, air-cooled Briggs and Stratton Engines). However, the majority of the experiments were conducted on the 205 CC displacement gasoline engine made by Briggs and Stratton. A digital, non-contact tachometer (Dr. Meter, Model DT-2234C) was used to measure the engine RPM. The dynamometer has a hydraulic brake, which restricts the flow of the pumped oil to vary the load on the engine. A 12 V DC power adapter controls the restriction valve attached to the intake pipe of the dynamometer. A force meter is attached (MA Instruments, Model #HF 1000, Figure 4) at a distance of 9 inches from the fulcrum (center) of the hydraulic pump. The force (lbf) multiplied by the length of the torque arm (9 inches or ¾ ft) gives the engine torque at a specified load in ft-lbs. The horsepower at each load is computed using the formula:

Engine HP = Torque (ft-Lb) x Engine RPM/5252, where, the 5252 is obtained by dividing 1 HP (or 33,000 lb-ft/min) by 2π.

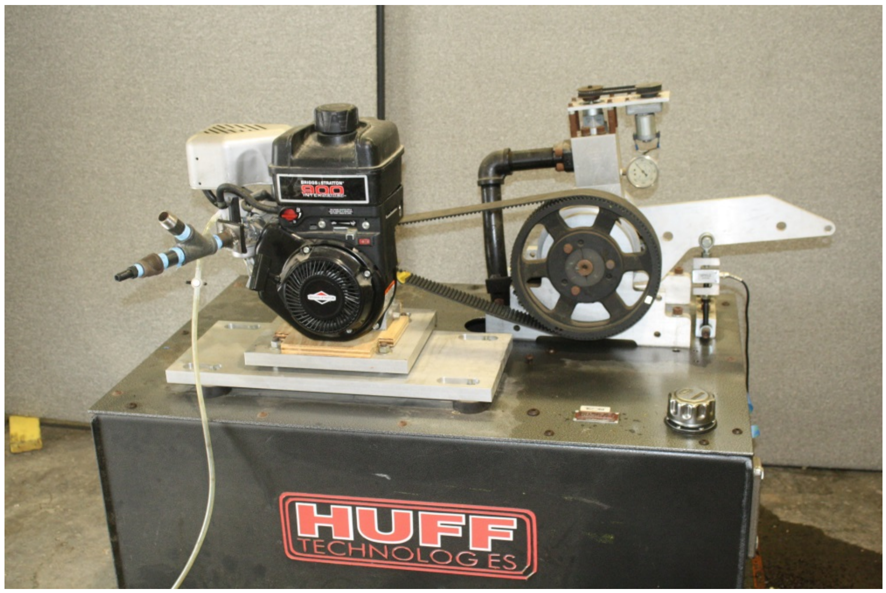


Figure 3: *Engine Testing Dynamometer made by Huff Technologies was used for testing the performance of all non-modified and modified gasoline engines.*

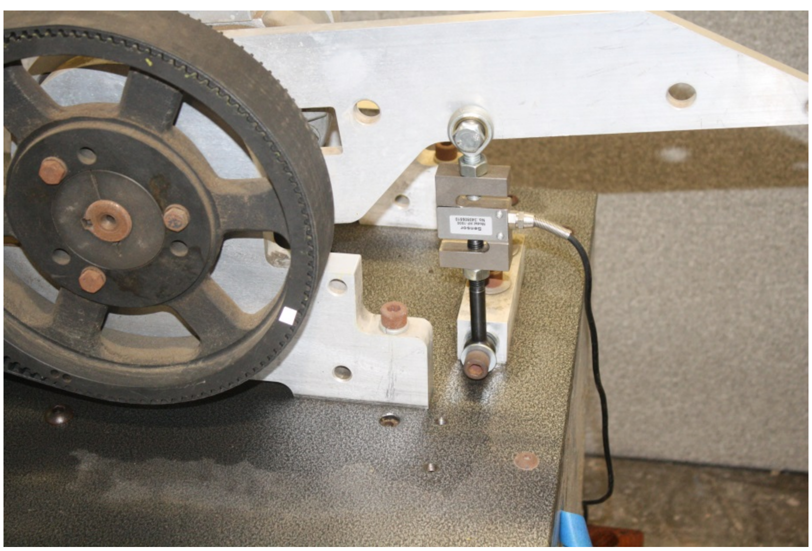


Figure 4: *A force meter attached to the torque arm measures the force exerted by engine at a specific distance from the fulcrum as a function of restriction of the hydraulic brake.*

Fuel Consumption Testing

For the fuel consumption test, the engine was set at a load (and rpm) that corresponds to the peak horsepower. The fuel consumption of the 205cc HP Briggs and Stratton engine before and after carburetor modification (and hydrogen injection) was quantified. A by-pass fuel line was attached to the gasoline fuel line entering the carburetor (clear tubing in Figure 2). Once the engine reached steady-state performance, the fuel from the gasoline tank was curtailed and the by-pass fuel line was opened. The end of the by-pass line was attached to a graduated plastic container. The fuel entering the carburetor in a given time period (1 minute) was read from the markings of the graduated plastic container.

External Alternator Addition to 150 CC Scooter

A 150 CC scooter (Taotao Group, Powermax 150, Figure 5) was purchased to test the regenerative braking. Four heavy duty alternators (with amperage rating from 70 to 120 amps, 12 volts; Figure 6) were purchased and tested. The scooter external components were stripped and an external mount was made to hold the alternator. The objective of this work task was to connect the external alternator to the engine crankshaft. Conceptually, whenever the brake was applied, the electromagnet portion of the alternator was fully powered and produces peak wattage. The produced power is used for electrolysis to produce oxy-hydrogen during the braking period. The gas produced during braking is reinjected into the engine during the first few seconds of acceleration. Although the overall process is conceptually sound, the final testing on the 150 CC scooter was not completed due to technical and resource limitations. The tight spacing in the engine compartment, the direction of rotation of the crankshaft (and the need for an opposite side rotation for the alternator), oxy-hydrogen gas back-flash safety, and physical limitations in extending the crankshaft were some of the hurdles faced by the investigative team. However, the PI proposes to re-attempt this task in the Fall of 2016.

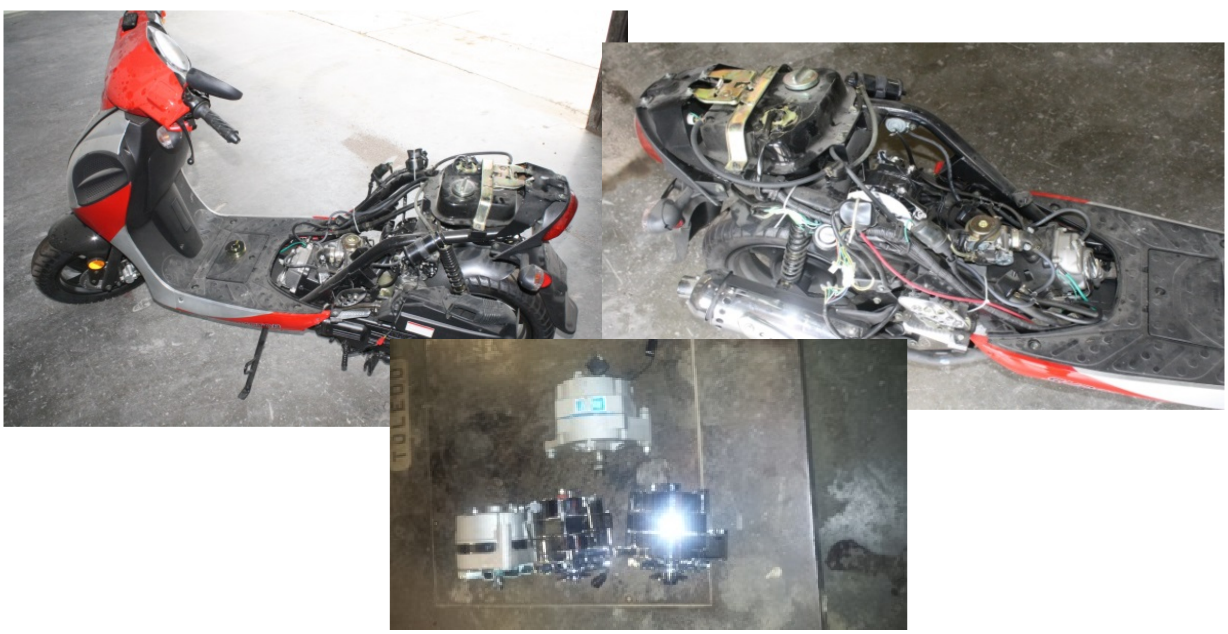


Figure 5: *Powermax 150 CC scooter was stripped down to accommodate a heavy duty alternator, which is anticipated to produce over 1000 watts of power during the braking period. Show here are the scooter after stripping, placement of the external alternator, and the various alternators that can be mounted externally to produce power.*

DISCUSSION OF RESULTS

Electrolysis and Oxy-Hydrogen Generation

For this study, an experimental system was set up to test electrolysis using an OGO electrolysis cell (www.ogohho.com). A power supply was used to apply 12 V and 4 A to the cell, and the rate of gas production was measured by timing the rate of water displacement by the gas in an inverted graduated cylinder. Based on Faraday's law of electrolysis for this current, the predicted rate of gas production is 7.00 mL/s, while the measured experimental rate was 3.69 ± 0.066 mL/s. For application in an internal combustion engine, the most important factor to consider is the energy efficiency of the hydrolysis system with respect to the hydrogen produced. This energy efficiency can be defined as the quotient of the HHV of hydrogen (39.4 kWh/kg-H_2) and the specific energy of the produced gas (also units of kWh/kg-H_2), which is equivalent to the energy input required to produce a certain volume of hydrogen. The average specific energy calculated using the experimental apparatus was 61.37 ± 1.10 kWh/kg-H_2, resulting in an energy efficiency of 64.242% ± 1.141%. In a review on the development of water electrolysis in 2014, 17 different hydrolysis systems showed a range of energy efficiencies of 52% to 67%.[x] Therefore, the measured efficiency of roughly 64% for the tested apparatus fits well within this range, indicating effective performance of the hydrolysis system.

Table 1: *HHO gas production from electrolysis experiments*

Trial	Power Source	Gas Generated (ml)	Time (s)	Current (A)	Predicted Gas Production Rate (mL/s)	Actual Gas Production Rate (mL/s)	Production Efficiency (%)	Specific Energy (kWh/kg-H2)	Energy Efficiency (%)
1	Batt Charger	600	168	4.07	7.00	3.57	51.0%	63.4	62.2%
2	Batt Charger	600	162	4.07	7.00	3.70	52.9%	61.1	64.5%
3	Batt Charger	600	158	4.07	7.00	3.80	54.2%	59.6	66.1%
4	Power Supply	300	511	0.87	1.50	0.59	39.2%	82.4	47.8%
5	Power Supply	200	583	0.5	0.86	0.34	39.9%	81.1	48.6%
6	Power Supply	280	719	0.65	1.12	0.39	34.8%	92.8	42.4%

Dynamometer Engine Testing

Both unmodified and modified engines were tested on the Huff Technologies Engine Dynamometer (Figure 3). For baseline establishment, the horsepower and torque curves for two different gasoline engines (205 CC and 250 CC displacement, 4-stroke, air-cooled Briggs and Stratton Engines) were first plotted (Figure 6a-b).

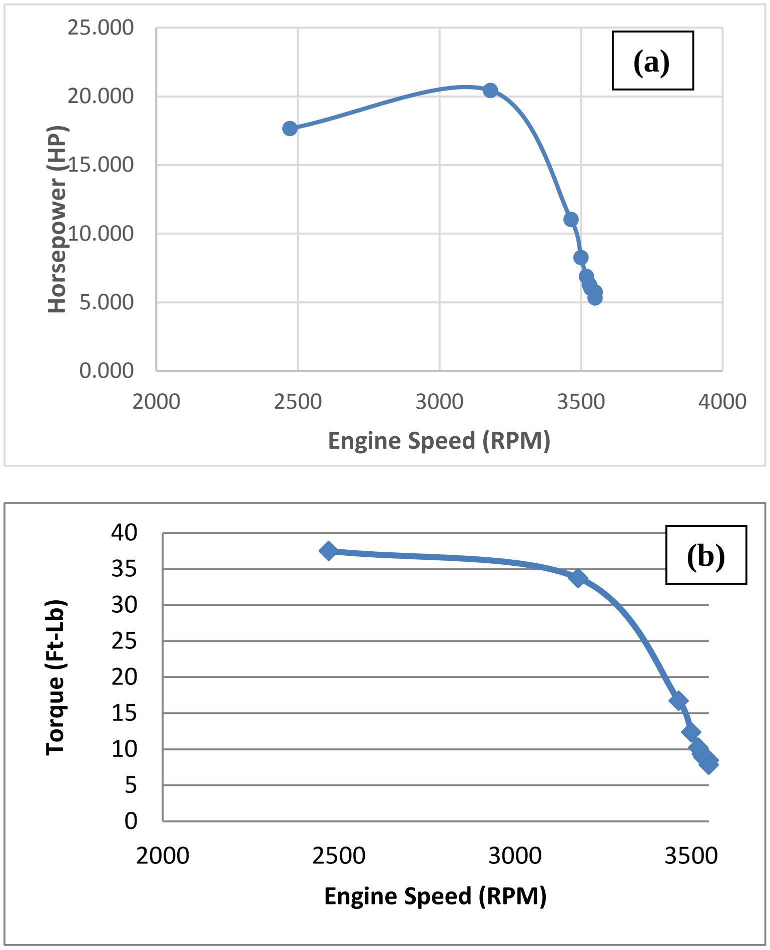


Figure 6a-b: Baseline Horsepower and Torque curves for the 250 CC displacement Briggs and Stratton Engine.

From Figure 6, it is clear that the tightening of the orifice in the hydraulic brake increased the torque and lowered the engine speed. The horsepower curve, as anticipated, had a peak value around 3,200 rpm as it is function of both engine speed and torque. The load from the hydraulic brake was increased only till the engine rpm dropped to 2500. At that point the engine was fighting hard to overcome the torque load. As this was a more expensive engine, further lowering of rpm was planned for the smaller and less expensive 205 cc engine.

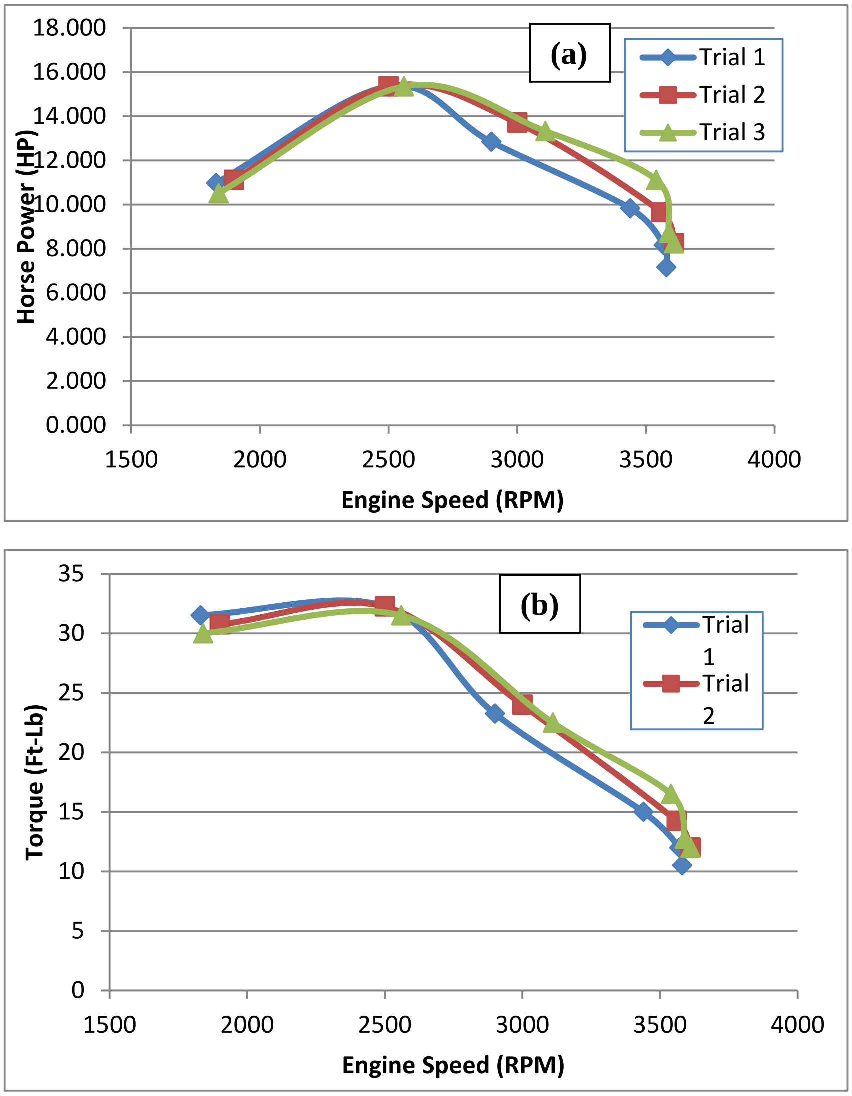


Figure 7a-b: Baseline Horsepower and Torque curves for the 205 CC displacement Briggs and Stratton Engine.

As compared to the bigger engine, the 205 CC engine was subjected to higher torque (hydraulic valve restricted more), which resulted in an rpm drop to 1,830 (Figure 7a-b). At that rpm the engine was stalling and any further increases in torque load would have caused excessive vibration, non-continuous operation, or engine stoppage. From these figures, the power and torque curves were as anticipated for a gasoline powered 4-stroke engine.

Once the baseline curves were generated, the 205 cc engine air intake, primary jet, and fuel lines were modified as indicated in the methodology. The modified engine was tested on the engine dynamometer. The finer primary jet (#77) restricted the flow of gasoline fuel to the engine. With the finer jet, the engine operation without any load (hydraulic valve fully open) was rough and the engine had excessive vibration. When load was applied to the engine, the engine died or its operation was erratic. When the choke on the carburetor was opened partially, the engine operated slightly better. The partial opening of the choke allows additional gasoline fuel to enter the engine, therefore, defeats the purpose of the project (gasoline fuel saving). However, the engine operation was smooth when a hydrogen flow that corresponded to 13.08% of the energy requirements of the engine was introduced through the modified air intake. Although the pattern of the curves are very different from the baseline power and torque curves, the modified engine performance at the peak load and HP was satisfactory (Figure 8a-b).

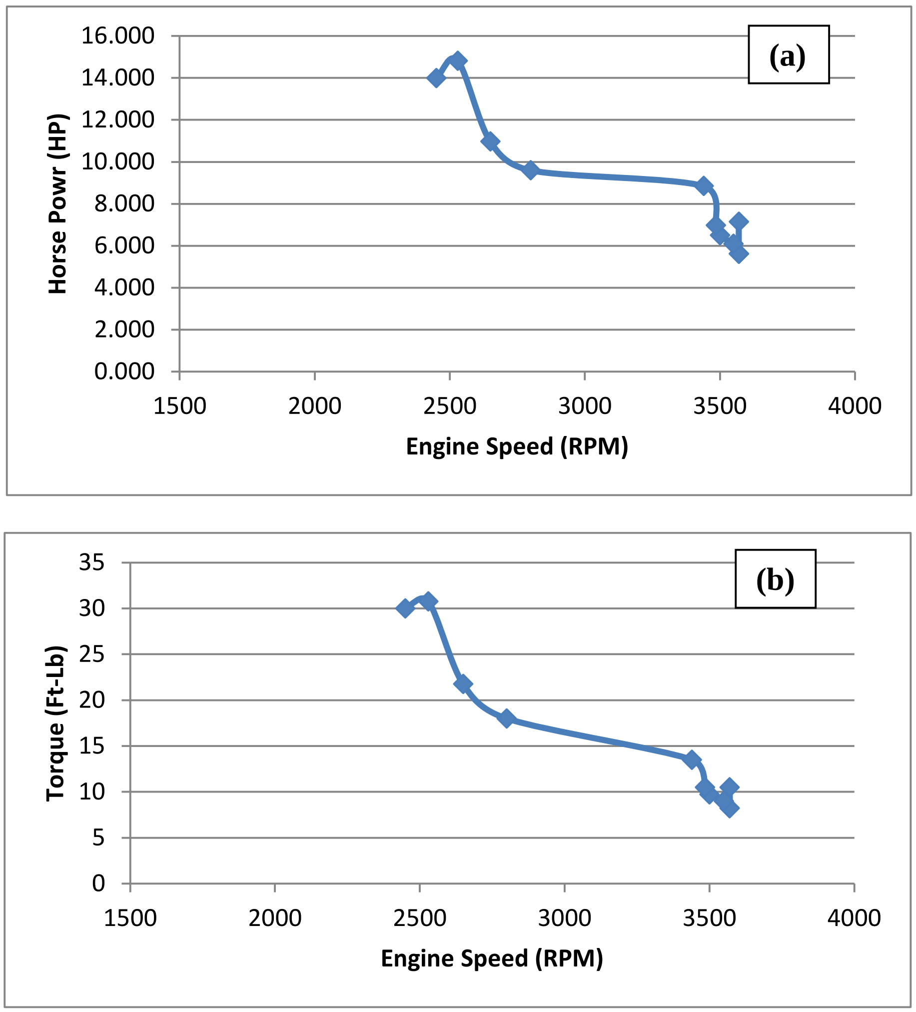


Figure 8a-b: *The power and torque curves of the modified (leaned) 205 CC engine that is supplemented with hydrogen***.**

When the engine dynamometer testing was repeated with both hydrogen and oxygen, the engine temperature quickly went up and heated the carburetor to unsafe temperatures. Therefore, further testing with both hydrogen and oxygen gases was not attempted. The excess oxygen in the fuel mixture likely improved the combustion efficiency and elevated the engine temperatures. Overall, the gas supplementation experiments indicated significant possible fuel savings and limitations of HHO supplementation. As HHO gas is anticipated to be supplemented only during the braking period which is anticipated to be in order of a few seconds, the increase in engine temperatures may not be a major concern for the real-world water-cooled engine. However, the engine heating and any water production within the engine chamber have to be further researched.

Fuel Consumption Testing

For the fuel consumption experiments the engine was tested both at the highest rpm (~3,600, no-load) and at an rpm that corresponds to the peak horsepower (~2,550 rpm). The fuel consumption of the 205 cc displacement Briggs and Stratton engine before and after carburetor modification (and hydrogen injection) was quantified. Results indicated significant savings in fuel consumption was evident when 13.08% of the gasoline (on a BTU basis) was substituted with hydrogen. Table 2 depicts the gist of the fuel consumption experiments. The engine efficiency was 135.4% due to hydrogen supplementation. It is important to note that the energy content of the hydrogen is not accounted in this calculation as it is anticipated to come from regenerative braking during the stopping of the vehicle. However, it is not clear how a 13.1% substitution by hydrogen can result in 59% gasoline savings. It is very likely that hydrogen assisted in improved combustion properties of the mixture. Before drawing any conclusions of synergistic benefits of hydrogen supplementation, it is important to repeat the experiments with multiple engines and confirm the current findings. Furthermore, it is important to test the engine emissions to ensure that the engine is not running too lean and releasing excessive quantities of pollutants.

Table 2: Fuel Consumption of the unmodified and modified 205 cc gasoline engine.

Fuel Jet #	Run Details	Engine RPM	Gasoline Consumption (mL/min)	Specific Fuel Consumption (g-fuel/kWh)	Power Output (HP)	Engine Efficiency (%)
81	Choke off, No gas supplementation	2570	23.7	89.8	15.4	83.689%
81	Choke off, No gas supplementation	3600	14.3	102.0	8.2	73.674%
77	Choke on, No gas supplementation	3600	16.7	118.6	8.2	63.340%
77	13.08% Hydrogen Addition, Choke Off	2530	9.7	38.4	14.8	135.4%

External Alternator Addition to 150 CC Scooter

A 150 CC scooter was purchased to test the regenerative braking. Four heavy duty alternators were purchased and tested. The scooter external components were stripped and an external mount was made to hold the alternator. The objective of this work task was to connect the external alternator to the engine crankshaft. Conceptually, whenever the brake was applied, the electromagnet portion of the alternator was fully powered produces peak wattage. The produced power is used for electrolysis to produce oxy-hydrogen during the braking period. They gas produced during braking is reinjected into the engine during the first few seconds of acceleration. Although the overall process is conceptually sound, the final testing on the 150 CC scooter was not completed due to technical and resource limitations. The tight spacing in the engine compartment, the direction of rotation of the crankshaft (and the need for an opposite side rotation for the alternator), oxy-hydrogen back-flash safety, and physical limitations in extending the crankshaft were some of the hurdles faced by the investigative team. However, the PI proposes to re-attempt this task in the Fall of 2016. The PI wishes to seek additional grants, including LSU LIFT 3 grants to further validate the research findings.

CONCLUSIONS

The engine dynamometer experiments on un-modified and modified air-cooled gasoline engines supported the proposition that lower amounts of gasoline is needed for engines that are supplemented with hydrogen. On a more positive note, results indicated that there may be a synergistic effect of hydrogen substitution on gasoline fuel savings. However, further studies have to be done to validate and confirm the findings. Based on the findings from the seed grant, the after-market pseudo-hybrid technology appears to be viable technology. Due to promising initial results and the massive economic potential, the PI feels that this technology at the least warrants a deeper and thorough investigation.

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RECOMMENDATIONS

The possible synergistic effect from hydrogen supplementation needs to be further investigated. Due to time and budgetary constraints, the experiments were not repeated multiple times with several engines. Before any conclusions can be drawn on possible fuel savings, it is important to reconfirm the findings on a full-scale, 4-wheeled automobile. Engine emissions are one aspect that was not included in the present study. Although, hydrogen and oxygen supplementation is anticipated to lower the emissions, it is critically important to test the emissions and water formation within the engine compartment due to HHO supplementation.

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