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Reduction of fuel consumption in gasoline engines by introducing HHO gas into intake manifold

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ABSTRACT

Brown's gas (HHO) has recently been introduced to the auto industry as a new source of energy. The present work proposes the design of a new device attached to the engine to integrate an HHO production system with the gasoline engine. The proposed HHO generating device is compact and can be installed in the engine compartment. This auxiliary device was designed, constructed, integrated and tested on a gasoline engine.

Test experiments were conducted on a 197cc (Honda G 200) single-cylinder engine. The outcome shows that the optimal surface area of an electrolyte needed to generate sufficient amount of HHO is twenty times that of the piston surface area. Also, the volume of water needed in the cell is about one and half times that of the engine capacity. Eventually, the goals of the integration are: a 20–30% reduction in fuel consumption, lower exhaust temperature, and consequently a reduction in pollution.

1. Introduction

The increasing demand for petroleum fuel associated with limited non-renewable stored quantities has resulted in a huge increase in crude oil prices. In the last few years, ordinary people experienced this by paying more at the pumps. Consequently we have seen a shift toward automobiles that consume less fuel. This has encouraged researchers to seek an alternative fuel that can be used in engines without the need for a dramatic change in the vehicle design. It has been shown that using pressurized hydrogen gas as a fuel in internal combustion engines (IC engines)[1] has many advantages such as more engine power and lower pollutant concentrations in exhaust gases [1,2]. As part of this advancement, studies on improving the performance of the internal combustion engine have been developed at Mutah University laboratories in the last few years. Some of these studies have focused on the reduction of cylinder liner wear, the filtration process, fuel mixing processes and the introduction of the fuel cell (FC). Research findings on the FC are presented in this work. An auxiliary circuit, with the FC being its main part, was designed and tested after installation on an actual engine. Many advantages were gained after installing the device behind the carburetor of the engine, as shown in Fig. 1. These include but are not limited to the following: a relatively efficient mixing of the elements (gasoline and air) inside the intake manifold, improved fuel economy, increased stability of the engine and reduced emission. The scope of this work is to introduce some of the hydrogen advantages while maintaining the original specifications of the engine. This may be attained by introducing an HHO cell to the

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[1] Brown's gas: HHO; FC: Fuel Cell; IC Engine: Internal Combustion Engine.

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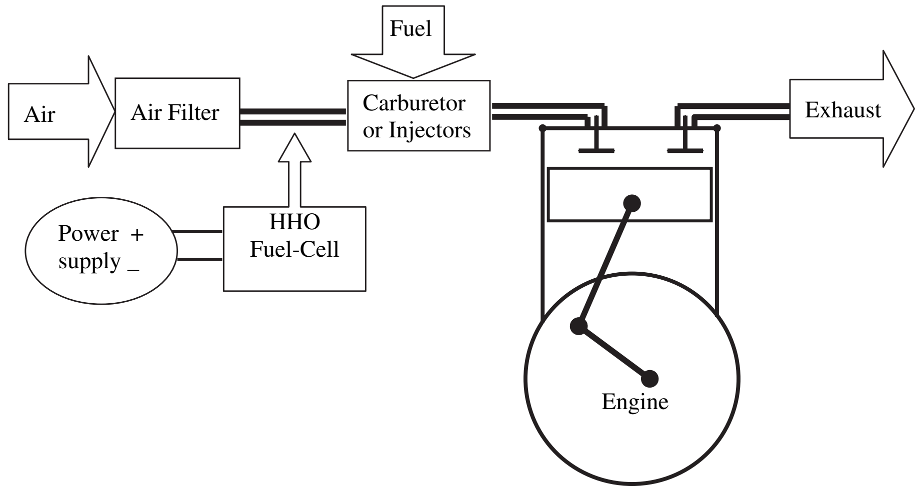

Fig. 1 – Schematic illustration of the designed fuel cell installed on the engine.

fuel supply system, so that a fuel mixture of gasoline and HHO gas is obtained. A compact unit for generating HHO gas was designed to fit the engine specifications and to be installed in the engine compartment next to the radiator.

2. Theoretical background

2.1. *Properties and use of hydrogen*

There is a considerable research effort in the United States, Europe, and Japan directed towards developing a "hydrogen economy", in which hydrogen would replace oil and natural gas for most uses, including fuel for transportation [3], according to Shinnar. He also listed six inherent fallacies of the supposed advantages of the hydrogen economy, as compared to the electric economy based on a mixture of fossil fuels, solar and nuclear energy. In both cases, the ultimate phase would be an economy based on solar and nuclear energy [3].

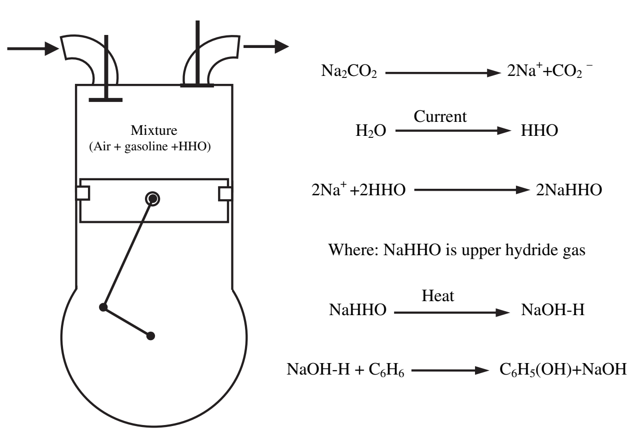

Fig. 2 – Schematic sketch of the engine showing the chemical reactions between air, gasoline, and HHO that take place inside the engine.

Momirlan, and Veziroglu [4] elaborated upon the hydrogen technology, economics, environmental impact, special system applications and hydrogen energy status around the world at the end of the 20th century. They also participated in establishing hydrogen organizations and associations, which organized projects, published periodicals and held conferences.

Santilli [5] showed that studies on the electrolytic separation of water into hydrogen and oxygen date back to the 19th

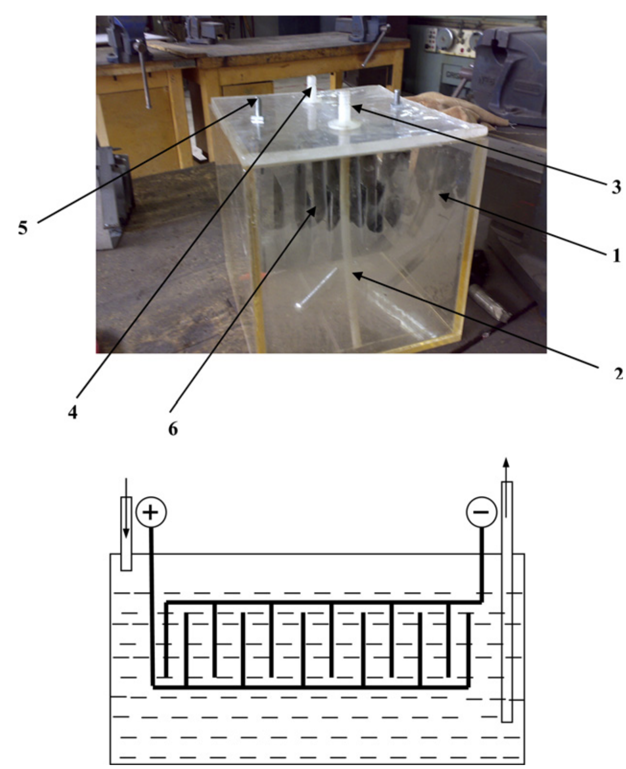

Fig. 3 – A photograph and a schematic diagram showing the main components of cell B (1-Plexiglas box, 2-Intake air tube, 3-Iintake valve, 4-Outlet valve, 5 -Electrode pole, 6-Stainless steel plates).

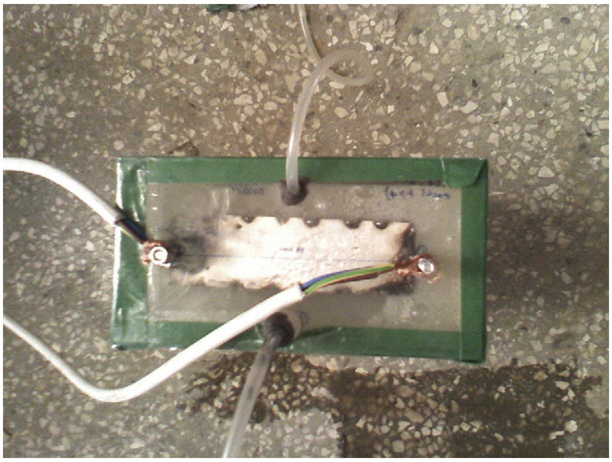

Fig. 4 – Top view photograph of cell C.

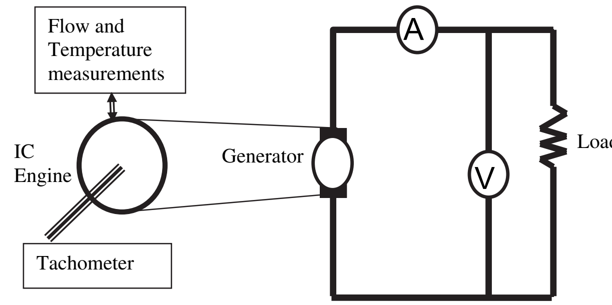

Fig. 5 – Schematic diagram showing the electrical circuit layout of the measuring system.

century. More recently, as Santilli mentioned, there has been considerable research in the separation of water into a mixture of hydrogen and oxygen gases. These studies were initiated by Yull Brown in 1977 via equipment generally referred to as electrolyzers and the resulting gas is known as "Brown's gas" or HHO.

Dunn in his important paper [6] indicated that research and development, incentives and regulations, and partnerships with industry had sparked isolated initiatives. But stronger public policies and educational efforts are needed to accelerate the process. Decisions made today will likely determine which countries and companies seize the enormous political power and economic prizes associated with the hydrogen age now dawning.

Schulti et al. in [7], after reviewing the existing literature on acceptance, risk perception and customer satisfaction, described the development of a model that illustrates important aspects in influencing a person's attitude toward a new product. "Values", "wants" and "perception" are the three components found to influence acceptance. The consumers themselves are affected by "social background" and "experience". Schulti et al. gave suggestions on how to use marketing methods, education projects and product exposure in order to maximize the likelihood of a successful introduction of hydrogen as an alternative fuel.

On the other hand, Hekkert et al. [8] analyzed and evaluated the German Research and Development system related to the development of hydrogen technology for automobile applications over the period 1974–2002. Their paper focused on the analysis of the main technological trends, the role of governments in steering the transition and the evaluation of the speed and direction of the transition to hydrogen. They showed that the interest in hydrogen is increasing rapidly and that overall the variety in research projects is increasing. Different governments play an active role in stimulating research and development, which broadens the variety of research topics. However, the gap between governments and industry may be too large to lead a significant influence of policy efforts. In the end, they therefore recommend stronger policy coordination to counteract the risks of premature lock-in in suboptimal hydrogen technologies.

Barreto et al. [9] described a long-term hydrogen-based scenario of the global energy system in qualitative and quantitative terms illustrating the key role of hydrogen in a long-term transition toward a clean and sustainable energy future. They showed that FC and other hydrogen-based technologies play a major role in a substantial transformation toward a more flexible, less vulnerable distributed energy system which meets energy needs in a cleaner, more efficient and cost-effective way. Hydrogen is the most abundant element in our universe [10]. In addition to being a component of all living things, hydrogen and oxygen together make up water, which covers 70 percent of the earth. In its pure form, a hydrogen molecule is composed of two hydrogen atoms (H_2) which is a gas at normal temperature and pressure with only seven

Table 1 – Specifications of Honda G200 engine used in this study [23].

Bore stroke	67 × 56
Displacement	197 cm^3
Compression power Ratio	6:5:1
Maximum Torque	1.06 kg-m/2500 rpm
Fuel Tank capacity	3.5 liter
Oil capacity	0.7 liter
Diminution (L × W × H)	337 × 375 × 425 mm
Dry Weight	15 kg

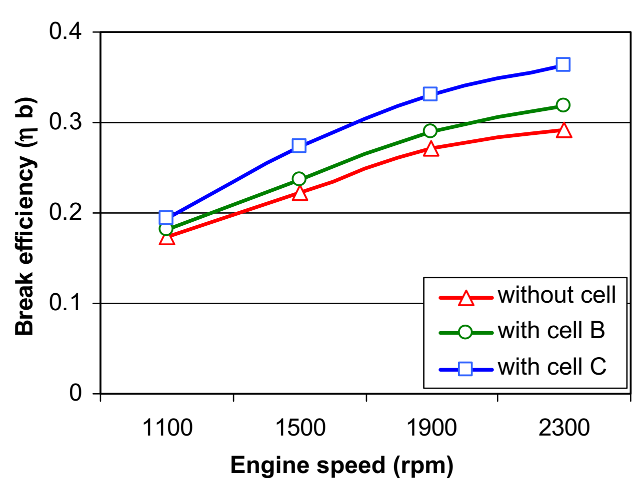

Fig. 6 – Plot showing the effect of using cell B and cell C on the brake efficiency (ηb) with variable engine speed (rpm).

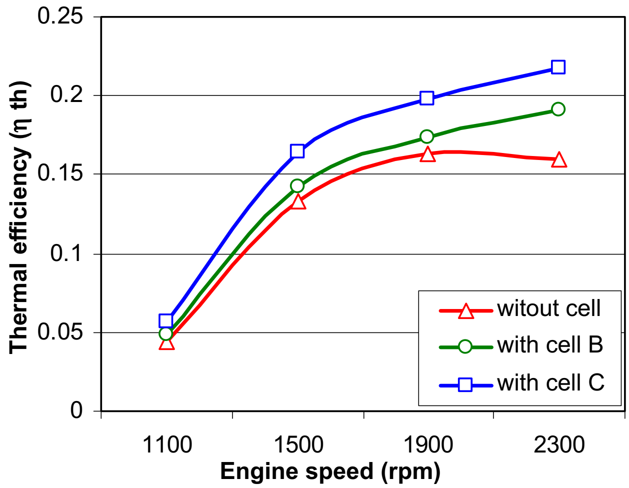

Fig. 7 – Plot showing the effect of using cell B and cell C on the thermal efficiency (ηth) with variable engine speed (rpm).

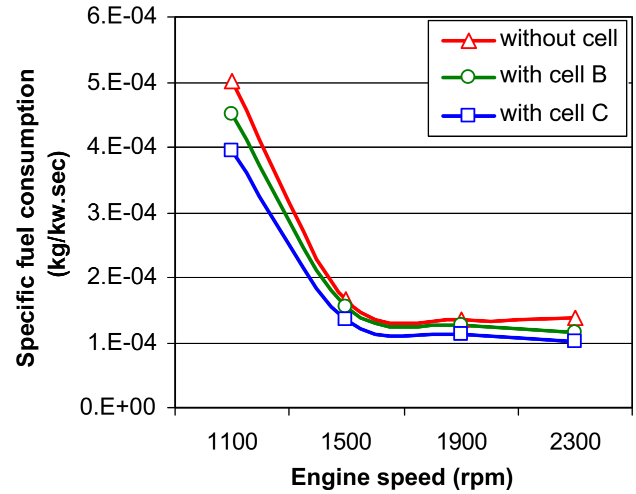

Fig. 9 – Plot showing the effect of using cell B and cell C on the specific fuel consumption (kg/kw.sec) with variable engine speed (rpm).

percent the density of air. Moreover, it is not a corrosive gas and can be used in engines with no toxic effects to humans. It ranks second in flammability among other gases, but if and when it leaks, hydrogen rises and diffuses to a nonflammable mixture quickly. Hydrogen ignites very easily and burns at a high temperature, but tends to burn out quickly. A mixture of hydrogen and air will burn when it contains as little as four percent up to as much as seventy five percent of hydrogen in the mix. This is a very wide flammability range [e.g., 10].

2.2. *Fuel cell (FC) and HHO generation*

FC is a fuel supply device containing several parts that demonstrate the real possibilities of how hydrogen can be used as a 100% clean fuel for cars in the future. Research on FC is currently going on all around the world. Open literature [10–22] and numerous web sites (too many to be listed here) have discussed the FC in detail and in all aspects.

The cell used in our experiments is an electrolyte cell in which distilled water converts to HHO. Sodium bicarbonates must be added gradually to assure heat generation control. The generated gas can be easily injected into the combustion chambers, then sparked and burned (see Fig. 2).

The HHO gas comes from the separation of water molecules H–OH. It has high calorific value and 1 kg of HHO is three times as potent as gasoline.

The cell plates have an anode and a cathode. The electric current enters the anode and then passes to the cathode through the electrolyte. The anode and cathode are made of the same materials.

2.3. *HHO injection inside engine system (see Fig. 2)*

Adding HHO to the fuel-air mixture has the immediate effect of increasing the octane rating of any fuel. Octane rating indicates how much a fuel can be compressed before it ignites. This fact causes the fuel-air mixture (without HHO) to ignite

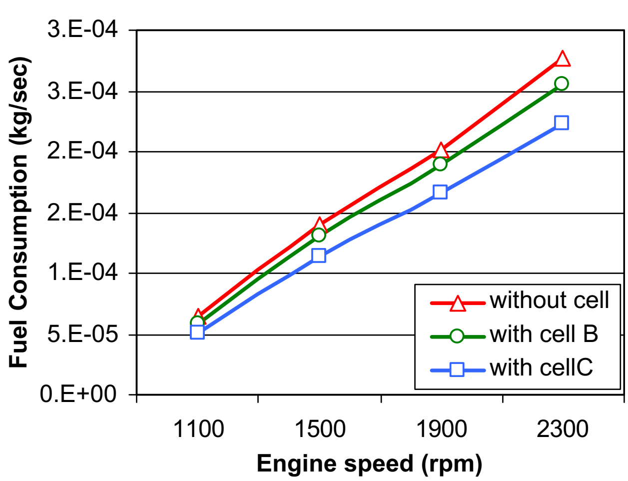

Fig. 8 – Plot showing the effect of using cell B and cell C on the fuel consumption (kg/sec) with variable engine speed (rpm).

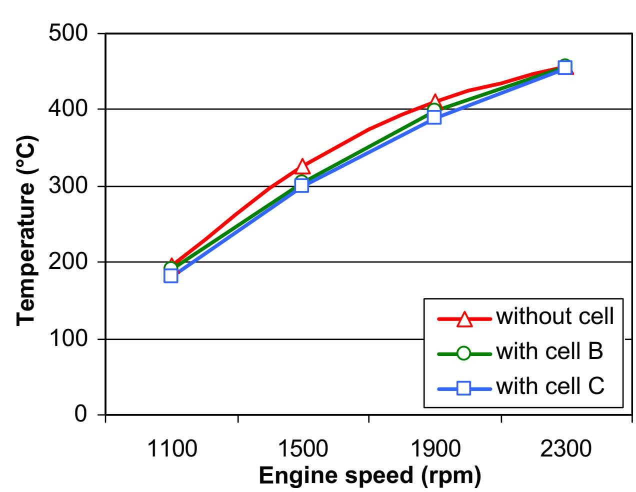

Fig. 10 – Plot showing the effect of using cell B and cell C on exhaust temperature (°C) with variable engine speed (rpm).

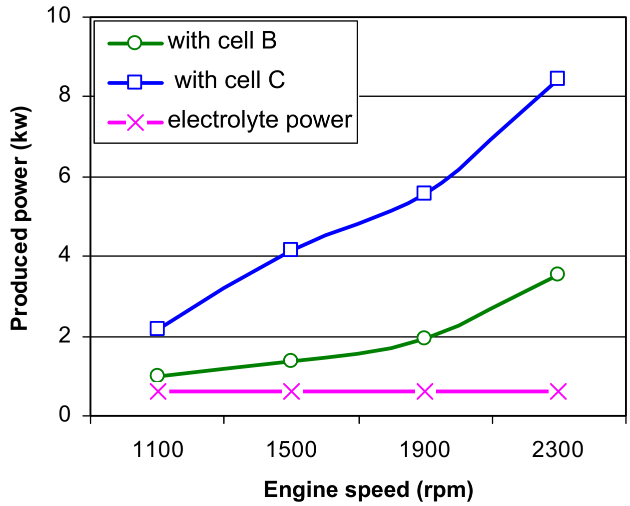

Fig. 11 – Plot showing the effect of using cell B and cell C on produced power (kw) with variable engine speed (rpm). The power supply curve is shown.

long before it reaches the top dead center (TDC). This process makes it less efficient because the explosion of gas fumes pushes the piston down and out of sequence. It goes too early a little in reverse, and therefore causes a "knocking" noise and produces less power. HHO makes regular low-grade fuel ignite with higher performance like a high-octane gasoline. A higher octane rating produces more power because combustion is much closer to TDC. The new mixture (air, gasoline and HHO) has a chance to turn into mechanical torque (rotary push) without knocking. Each piston transfers more energy during its combustion cycle, so combustion becomes more efficient. More efficient combustion means less fuel consumption.

3. Experimental rig and results

3.1. *Description of the proposed fuel cells (FC)*

Many models of the FC were made and tested on the engine. These models vary in the basic dimensions or in size. The size is defined as the ratio between the surface area of the cell and the area of the piston. This ratio is found to be the main parameter for matching the engine and the FC. Experimentally, some of these models showed good results while others did not. Only the two models, which produced significant results will be presented here and will be designated as FC (B) and FC (C).

3.1.1. *Dimensions of cell type (B)*

As shown in Fig. 3, this cell is constructed with one square meter plates of spiraled electrolyte (stainless steel-grade 316L) arranged inside a Plexiglas box with the required fittings and piping. The input of the cell is distilled water and sodium bicarbonate that work as the electrolyte. The output gas (HHO) can easily be injected into the combustion chambers in order to spark and burn. As a result of experience, Stainless Steel-grade 302 or grade 304 for the cathode (the minus volt wire) may be used, but grade 316L is essential for the anode (the plus volt wire). If the same material is used in the same cell for the anode and the cathode, it is important always to mark each one. This cell has been designed and built at Mutah University workshops with a volume capacity of 8 liters.

3.1.2. *Dimensions of cell type (C)*

The size of the type(C) cell is one-half the dimension of the type (B) cell (See Fig. 4). The materials and connection of this cell are identical to that of type (B) cell.

3.2. *Description of the experimental rig and measurement techniques*

A Honda single-cylinder, spark-ignition, air-cooled engine (the Honda G200 engine [23]) was used in the test. Engine specifications are shown in Table 1. Constant load with variable speed (from 1000 to 2500 rpm) performance tests were carried out on the engine. Auxiliary equipment were used for data measurements: tachometer for engine speed; voltmeter for cell voltage; thermometers for ambient temperature; thermocouples for exhaust gas temperature; clamp meter for current measurements and flow meter for fuel consumption (Graduated Beaker connected with carburetor). A power supply was also used to provide the FC with

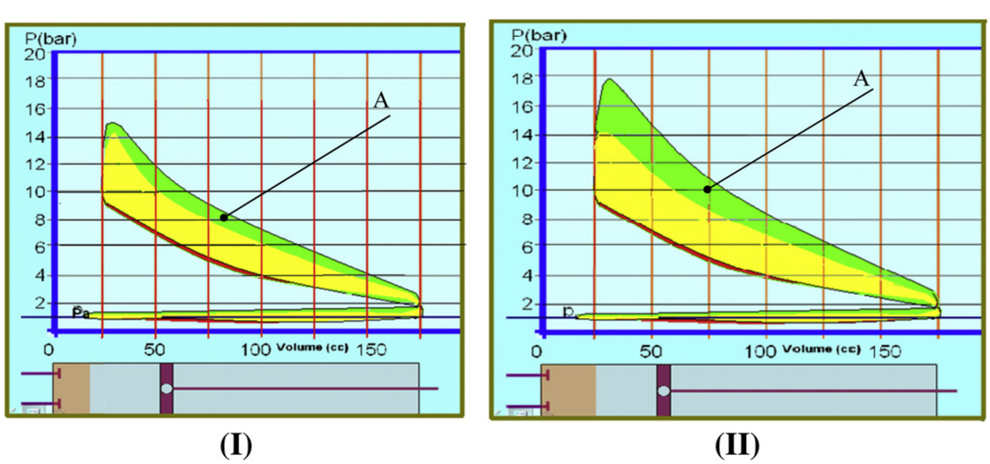

Fig. 12 – P–V diagram of the engine showing the amount of useful work (A);(I) with cell B; (II) with cell C.

the necessary power (30A × 0–20DC V). Fig. 5 shows the measuring circuit of these devices.

3.3. *Experimental set-up of integrating the FC with the engine*

It is very important to explain how the FC is integrated into the engine compartment safely. It should be mounted, leveled, and secured so that it will not bounce around when the vehicle hits bumps. The FC was positioned so that it can be easily accessed and can be conveniently cleaned, serviced, inspected and filled with water. The FC must be placed far away from hot points of the engine.

In laboratory, the output pipe of the FC is linked to the intake manifold of the engine. The generated HHO gas is sucked directly into the engine during the induction stroke.

3.4. *Experimental results*

The performance test was performed on the test engine (G200) before and after attaching the FC. The calculations have been performed according to the standard equations that can be found in many IC engine textbooks.

Figs. 6–12 show the effects of the FC on the engine performance. Fig. 6 shows the effect of the FC on the break efficiency, revealing an increase in the efficiency of about 3% for Cell B and 8% for Cell C. Fig. 7 shows a similar trend for the thermal efficiency. Figs. 8 and 9 are concerned with fuel consumption and indicate a significant reduction, especially with Cell C. Fig. 10 shows the reduction of the exhaust temperature as a result of the FC that is a clear indication of better combustion and cleaner gases. Fig. 11 shows the additional power produced after using the FC (B) and (C). The P–V diagrams in Fig. 12 shows a comparison between cells (B) and (C). As can be seen, the shaded area (A) represents the additional power gained after installing the FC on the engine. It is clearly seen that cell (C) produces more power than cell (B).

4. Conclusions

In this work, FC for HHO gas generation was designed, manufactured and tested. The generated HHO gas was introduced to the air stream just before entering the carburetor of a Honda G 200 engine. The following conclusions can be drawn:

1. The use of HHO in gasoline engines enhances combustion efficiency, consequently reducing fuel consumption and thereby decreasing pollution.
2. The optimal size of the FC is when the surface area of an electrolyte needed to generate sufficient amount of HHO is twenty times that of the piston surface area. Also, the volume of water needed in the cell is about one and half times the engine capacity.
3. The FC which can be used is simple, easily constructed, and easily integrated with existing engines at low cost (approximately 15 US dollars for each cylinder).

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