HYDROGEN POWERED LAWNMOWER

MOHD RAFI'UDDIN BIN RAMLAN

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ABSTRACT

The study and analysis of a hydrogen powered lawnmower are described. Most of the commercial lawnmower is originally powered by gasoline carbureted 2-stroke engine. The carbureted 2-stroke engines are characterized by high levels of hydrocarbon, carbon monoxide, and particulate matter emissions. Despite its poor emissions, carbureted 2-stroke engines remain a popular power source for small appliances like lawnmower because of its low cost and high power to weight ratio. The presence of hydrogen as the fuel for the internal combustion engine can improve the quality of emissions as well as the fuel consumption. The commercial model that was originally running on gasoline is adapted to hydrogen by making adjustments to the fuel delivery system. The fuel delivery system modified to use hydrogen as the sole fuel in the internal combustion engine. The original carburetor system is replaced with the fuel injection system. Re-designing the fuel delivery system can be effective in reducing or eliminating irregular combustion due to premature ignition and backfires. The hydrogen needed for the engine is generated from electrolysis in a hydrogen generator which turns water as an electrolyte into HHO or hydrogen. The measure for engine design or conversion also discussed.

ABSTRAK

Tesis ini membincangkan hasil kajian dan analisa ke atas pemotong rumput yang menggunakan gas hidrogen sebagai bahan bakar di dalam enjin. Kebanyakan pemotong rumput yang berada di pasaran dijana oleh enjin yang menggunakan sistem karburetor 2-lejang dan menggunakan petrol sebagai bahan bakar di dalam enjin. Sistem karburetor 2-lejang ini telah dikategorikan sebagai sistem yang menghasilkan hidrokarbon, karbon monoksida dan zarah-zarah yang tercemar hasil pembakaran dalam enjin pada kadar yang tinggi. Walaupun menghasilkan kadar pencemaran yang tinggi, sistem ini terus menjadi pilihan popular untuk diaplikasikan kepada alatan yang berkuasa kecil seperti pemotong rumput kerana kosnya yang rendah dan mempunyai kadar penghasilan kuasa yang tinggi jika dibandingkan dengan saiznya yang kecil. Penggunaan gas hidrogen sebagai bahan api dalam enjin dapat meningkatkan kualiti sisa asap yang dilepaskan oleh enjin. Penggunaan gas hidrogen juga dapat mengurangkan kadar pengunaan minyak. Pemotong rumput yang menggunakan petrol sebagai bahan bakar diubahsuai sistem penghantaran minyaknya supaya dapat beroperasi menggunakan hidrogen sebagai bahan bakar. Sistem penghantaran minyak diubahsuai untuk membolehkan hidrogen bertindak sebagai bahan bakar tunggal dalam enjin. Sistem karburetor yang asal digantikan dengan sistem suntikan bahan api. Pengubahsuaian sistem penghantaran minyak dapat mengurangkan atau mengatasi pembakaran yang tidak sempurna yang disebabkan oleh pembakaran awal dan pembakaran yang berlaku di luar silinder enjin. Dalam analisis ini, hidrogen yang digunakan dijana dari proses elektrolisis. Langkah-langkah untuk pengubahsuaian enjin juga dibincangkan dalam tesis ini.

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LIST OF ABBREVIATIONS

A/F	Air/fuel ratio
BTDC	Before top dead center
CO	Carbon monoxide
DC	Direct current
DI	Direct injection
EFI	Electronic fuel injection
EGR	Exhaust gas recirculation
EPC	Exhaust port closed
EZEV	Equivalent zero emission vehicle
H_2	Hydrogen
H_2O	Water
HC	Hydrocarbon
HHO	Oxyhydrogen
ICE	Internal combustion engine
N_2	Nitrogen
NO	Nitric oxide
NO_x	Nitrogen oxides
O_2	Oxygen
PM	Particulate matter
RPM	Revolution per minute
WOT	Wide open throttle

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Fossil fuel prices have never been more volatile, influenced most by current global issues at that current time. In the last few years, consumers experienced this and had to pay more at the pumps. The increasing demand for petroleum fuel associated with limited non-renewable stored quantities has resulted in a huge increase in crude oil prices. Besides, the current method of providing the world's energy demand, based primarily on fossil fuel, is becoming increasingly untenable. Current fossil fuel reserves now are clearly exhaustible. The difficulty of controlling prices and the uncertain reserves are strong reasons for researchers to find new source of energy that can be renewing yet environment friendly.

Hydrogen is seen as one of the important energy sources in the future. The use of hydrogen as an energy carrier is one of the options put forward in most research for a sustainable energy system. There are many considerable research that been done directed towards developing the hydrogen in which it could be the replacement for oil and natural gas for most uses, including fuel for transportation. Hydrogen driven vehicles reduce both local as well as global emissions. Hydrogen creates virtually zero harmful emissions and potentially high efficiency at the point of its use.

There are many appliances around us that use gasoline as the main fuel sources. A lawnmower is a machine that uses a revolving blade or blades to cut a lawn at an even height. Most lawn mower is powered by internal combustion. Such engines are usually two-stroke cycle engines, running on gasoline (petrol) or other liquid fuels. Lawn mower usually uses carburetor system. Carbureted 2-stroke engines are characterized by high levels of hydrocarbon (HC), carbon monoxide (CO), and particulate matter (PM) emissions. The high hydrocarbon emissions from carbureted two-stroke engines result from the scavenging process used. Scavenging refers to the process by which the burned exhaust gasses are flushed from the engine. The high carbon monoxide emissions result from rich air to fuel ratio typically seen in these engines.

The lawn mower does create pollution due to the combustion in the engine. Many researches been done to seek an alternative source of fuel that can be used in lawn mower engine without the need of major modification to the engines and also to the lawn mower design itself. The method that has been studied are the reduction of cylinder liner wear, the filtration process, fuel mixing processes and the introduction of the fuel cell. There also been commercialized lawn mower that using electric power. The disadvantage of using electricity is the lawn mower cutting range is limited by the electric cord.

1.2 BACKGROUND OF STUDY

In this project, the designing of hydrogen powered lawnmower will be conducted. Besides that the details phases of the hydrogen generator development, from concept design consideration to equipment selection, fabrication and finally the testing process will be studies. The project will be started with literature review to gather all the information related to hydrogen generator and hydrogen as the sole fuel in internal combustion engine. Literature review also will review the system of the internal combustion engine.

Next the design concept of hydrogen powered lawn mower will be evaluated in order to select the best system to be applied on hydrogen powered lawn mower.

This process will be followed by fabrication process in order to develop the design. Fabrication process involves all basic mechanical processes such as grinding, drilling, cutting and etc. Once the fabrication process finished, the hydrogen generator, the new system for fuel delivery will be attached to the lawn mower. The test run will be conducted if all the component valid and functional well.

1.3 PROBLEMS STATEMENTS

This study is about the designing of and the lawn mower that powered by hydrogen and the hydrogen generator. The prototype will be designed before the real hydrogen powered lawnmower is produces. It is done to ensure better performance of the design especially for high cost products. The hydrogen generator was fabricated to produce the hydrogen gas and see how efficient the energy was compared to other energy sources. Its successful development could be apply to other transportation such as car or motorcycle. This project will focus on the hydrogen as the sole fuel in internal combustion engine. Whole system for the engine and hydrogen generator needed to be stated clearly.

1.4 OBJECTIVES

The main objectives of the study are:

i. To study hydrogen powered lawnmower system
ii. To analyses the suitable system for hydrogen powered lawnmower

1.5 SCOPES

To accomplish the objectives, these are the scopes of the project:

i. Develop hydrogen generator as hydrogen will be the fuel for the hydrogen powered lawnmower.
ii. Study and identify the new system for the lawn mower engine to be converted into hydrogen internal combustion engine.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY

The idea of operating an internal combustion engine on hydrogen is almost as old as the internal combustion engine itself. The man who is responsible in inventing this concept is Francois Isaac de Rivaz. In 1807 he invented an internal combustion engine that used a mixture of hydrogen and oxygen for fuel [1]. For this engine Rivaz designed a car that is also the first internal combustion powered automobile. Patented by Jean Joseph Etienne Lenoir in 1860, a gas driven two-stroke engine with horizontal arrangement is considered the first successful internal combustion engine [1]. The engine was powered by hydrogen generated via the electrolysis of water. In 1933, Norsk Hydro operated an internal combustion engine vehicle on hydrogen produced from onboard reforming of ammonia [1]. Also In 1933, Erren Engineering Company proposed injecting slightly pressurized hydrogen into air or oxygen inside the combustion chamber rather than feeding the air-fuel mixture via a carburetor into the engine, a method that commonly resulted in violent backfiring. The patented system required special fuel injection and control mechanism but left the other engine components intact [1]. With hydrogen used as a booster, the system eliminated backfiring and achieved much better combustion of hydrocarbons with higher output and lower specific fuel consumption. In 1974, Musashi Institute of Technology introduced the first Japanese hydrogen-fueled vehicle, called Musashi 1, using a 4-stroke hydrogen engine and high pressure storage. The Musashi 2, introduced in 1975, was equipped with hydrogen manifold injection on a 4-stroke engine in combination with liquid hydrogen storage. In 1977, Musashi 3 was presented using a spark-ignited 2-stroke engine with hydrogen Direct Injection.

2.2 PROPERTIES OF HYDROGEN

The attractiveness of hydrogen lies in the variety of methods to produce hydrogen as well as the long-term viability. The variety of methods to produce energy from hydrogen (internal combustion engines, gas turbines, fuel cells), virtually zero harmful emissions and potentially high efficiency at the point of its use [2]. Hydrogen is the most abundant element in our universe. 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 percent the density of air [2]. 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 [1]. 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.

Besides that hydrogen also has its own combustive properties. The properties that contribute to its use as a combustible fuel are:

(i) Wide range of flammability
(ii) Low ignition energy
(iii) High auto ignition temperature
(iv) High diffusivity
(v) Small quenching distance

(vi) High flame speed at stoichiometric ratios

2.2.1 Wide Range of Flammability

Hydrogen has a wide flammability range in comparison with all other fuels. As a result, hydrogen can be combusted in an internal combustion engine over a wide range of air-fuel mixtures. A significant advantage of this is that hydrogen can run on a lean mixture. A lean mixture is one in which the amount of fuel is less than the theoretical, stoichiometric or chemically ideal amount needed for combustion with a given amount of air. This is why it is fairly easy to get an engine to start on hydrogen. However there is a limit to how lean the engine can be run, as lean operation can significantly reduce the power output due to a reduction in the volumetric heating value of the air-fuel mixture [3].

2.2.2 Low Ignition Energy

Hydrogen has very low ignition energy. This enables hydrogen to ignite lean mixtures and ensures perfect ignition [3]. Unfortunately, this characteristic will cause the problem of premature ignition and flashbacks. This is because hydrogen that is low ignition energy will react with hot gases and hot spots on the cylinder.

2.2.3 High Auto Ignition Temperature

High auto ignition temperature has important implications when hydrogen-air mixture is compressed in cylinder. It is also important in determining what compression ratio an engine can use as the temperature rise during compression is related to the compression ratio [3]. The high auto ignition temperature of hydrogen allows larger compression ratios to be used in a hydrogen engine than in a hydrocarbon engine [3]. Higher compression ratio is important because it is related to the thermal efficiency of the system.

2.2.4 High Diffusivity

High diffusivity has ability to disperse in air considerably greater than gasoline [3]. It has two advantages. First, it facilitates the formation of uniform mixture of fuel and air. Second, hydrogen can disperse rapidly if there are any leak develops in the system. Therefore unsafe conditions can either be avoided or minimized.

2.2.5 Small Quenching Distance

Compare to gasoline, hydrogen has smaller quenching distance. Hydrogen flames travel closer to the cylinder wall than other fuels before they extinguish [5]. The hydrogen flame is more difficult to quench than gasoline flame.

2.2.6 High Flame Speed

In this condition, hydrogen engines can more closely approach the ideal cycle in term of thermodynamics. However the flame velocity decreases significantly at leaner mixture.

2.3 DIFFICULTY OF USING HYDROGEN

The properties of hydrogen that make it become desirable fuel for internal combustion engine also come with responsibility for abnormal combustion occur in combustion chamber. The hydrogen properties of wide range of flammability, low ignition energy, and high flame speed can result in abnormal combustion phenomena which is undesired in internal combustion engine.

2.3.1 Premature Ignition

The premature ignition (pre-ignition) is among the primary problem that has been encountered in the development of hydrogen fueled engine. Hydrogen fueled engines experience much greater pre-ignition phenomena than other internal combustion engine. This is because of hydrogen's lower ignition energy, wide flammability range and shorter quenching distance. Pre-ignition occurs when the fuel mixture in the combustion chamber becomes ignited before ignition by the spark plug, and results in an inefficient, rough running engine [5]. The pre-ignition occur during compression stroke. The factor that contribute to the pre-ignition occurrence are hot spark plugs or spark plugs electrode, hot exhaust port or other hot spots in the combustion chamber, residual gas or remaining hot oil particles from previous combustion events as well as residual charge can cause pre-ignition.

Measures to avoid pre-ignition include proper spark plug design, design of the ignition system with low residual charge, specifically designed crankcase ventilation, sodium-filled exhaust port as well as optimized design of the engine cooling passages to avoid hot spots. Hydrogen direct injection into the combustion chamber is another measure effectively reduces or eliminates the occurrence of pre-ignition depending on the injection strategy.

2.3.2 Backfire

Backfiring, or flash-back, describes combustion of fresh hydrogen-air charge during the intake stroke in the engine combustion chamber or the intake manifold. During intake stroke, the fresh hydrogen-air mixture is injected into the combustion chamber. When the fresh charge is ignited at combustion chamber hot spots, hot residual gas or particles or remaining charge in the ignition system, backfiring occurs, similar to pre-ignition. The main difference between backfiring and pre-ignition is the timing at which the phenomena occur. Pre-ignition occur during compression stroke whereas backfiring occur during intake stroke. Any measures that help avoid pre-ignition also reduce the risk of backfiring.

2.4 MEASURES FOR ENGINE DESIGN OR CONVERSION

Some features of engines designed for, or converted to hydrogen operation need to be modified. The desire to prevent the occurrence of abnormal combustion has led to most of the countermeasure put forward in the development of internal combustion engine.

2.4.1 Spark Plugs and Ignition System

Spark plugs for a hydrogen engine should have a cold rating and have non-platinum tips (electrodes). Cold rated spark plugs are recommended to avoid spark plug electrode temperatures exceeding the auto ignition limit and causing backfire. Cold rated spark plug also is one that transfer heat from the plug tip to the cylinder head quicker than a hot rated spark plug. This means the chances of the spark plug tip igniting the air/fuel charge is reduced. Spark plugs with platinum electrodes are to be avoided, as platinum can be a catalyst to hydrogen oxidation.

The ignition systems that use a waste spark system should not be used for hydrogen engines. This system energize the spark each time the piston is at top dead center whether or not the piston is on the compression stroke or on exhaust stroke. For hydrogen engine the waste sparks are the source of pre-ignition.

2.4.2 Fuel Delivery Systems

Re-designing the fuel delivery system can be effective in reducing or eliminating pre-ignition. The disadvantage of carburetor is that it is more susceptible to irregular combustion due to pre-ignition and backfires. The greater amount of hydrogen/air mixture within the intake manifold compounds the effects of pre-ignition.

One option is to use port injection system. The port injection fuel delivery system injects fuel directly into the intake manifold at each intake port, rather than drawing fuel in at a central point. Typically, the hydrogen is injected into the manifold after the beginning of the intake stroke. At this point conditions are much less severe and the probability for premature ignition is reduced. In port injection, the air is injected separately at the beginning of the intake stroke to dilute the hot residual gases and cool any hot spots. Since less gas (hydrogen or air) is in the manifold at any one time, any pre-ignition is less severe. The inlet supply pressure for port injection tends to be higher than for carbureted or central injection systems, but less than for direct injection systems.

The other option is to use direct injection. More sophisticated hydrogen engines use direct injection into the combustion cylinder during the compression stroke. By using direct injection, the fuel is injected during the intake port is close completely avoiding premature ignition during the intake stroke. Consequently the engine cannot backfire into the intake manifold. The power output of a direct injected hydrogen engine is 20% more than for a gasoline engine and 42% more than a hydrogen engine using a carburetor. Direct injection systems require a higher fuel rail pressure than the other methods.

2.4.3 Thermal Dilution

Hot spots in the combustion chamber that could initiate surface ignition or backfire are to be avoided or minimized. Pre-ignition also need to be avoided. The pre-ignition conditions can be curbed using thermal dilution techniques such as exhaust gas recirculation (EGR) or water injection. An EGR system recirculates a portion of the exhaust gases back into the intake manifold. The introduction of exhaust gases helps to reduce the temperature of hot spots, reducing the possibility of pre-ignition. Additionally, recirculating exhaust gases reduce the peak combustion temperature, which reduces NOx emissions. Typically a 25 to 30% recirculation of exhaust gas is effective in eliminating backfire. On the other hand, the power output of the engine is reduced when using EGR. The presence of exhaust gases reduces the amount of fuel mixture that can be drawn into the combustion chamber.

Another technique for thermally diluting the fuel mixture is the injection of water. Injecting water into the hydrogen stream prior to mixing with air has produced better results than injecting it into the hydrogen-air mixture within the in-take manifold. A potential problem with this type of system is that water can get mixed with the oil, so care must be taken to ensure that seals do not leak. Besides that, the delay of fuel introduction to create a period of air cooling is also the method to minimize the hot spots in the combustion chamber.

2.4.4 Engine Design

The most effective means of controlling pre-ignition and knock is to re-design the engine for hydrogen use, specifically the combustion chamber and the cooling system. A disk-shaped combustion chamber (with a flat piston and chamber ceiling) can be used to reduce turbulence within the chamber. The disk shape helps produce low radial and tangential velocity components and does not amplify inlet swirl during compression.

Since unburned hydrocarbons are not a concern in hydrogen engines, a large bore-to stroke ratio can be used with this engine. To accommodate the wider range of flame speeds that occur over a greater range of equivalence ratios, two spark plugs are needed. The cooling system must be designed to provide uniform flow to all locations that need cooling.

2.4.5 Crankcase Ventilation

Crankcase ventilation is even more important for hydrogen engines than for gasoline engines. As with gasoline engines, un-burn fuel can seep by the piston rings and enter the crankcase. Since hydrogen has a lower energy ignition limit than gasoline, any un-burn hydrogen entering the crankcase has a greater chance of igniting. Hydrogen should be prevented from accumulating through ventilation. Ignition within the crankcase can be just a startling noise or result in engine fire. When hydrogen ignites within the crankcase, a sudden pressure rise occurs. To relieve this pressure, a pressure relief valve must be installed. Positive crankcase ventilation is generally recommended due to un-throttled operation (high manifold air pressures) and to decrease hydrogen concentrations (from blowby) in the crankcase wide open throttle operation is used wherever possible to increase engine efficiency, resulting in high manifold air pressures. Thus, the pressure difference between the crankcase and the intake manifold, such as in throttled gasoline engines, is absent for some operating strategies of hydrogen engines, and thus cannot be used as a driving force for crankcase ventilation. This can be solved by using a venture placed in the intake.

2.4.6 Materials

The effects of hydrogen on the mechanical properties of iron and steels have been widely investigated. Regarding the embrittling effect of hydrogen, it is well known that the dominant effects are a decrease in ductility and true stress at fracture. Hydrogen embrittlement of steels can be classified into three main types. First, hydrogen reaction embrittlement arises because of the generation of hydrogen on the surface as a result of a chemical reaction. Second, Environmental embrittlement takes place in the hydrogen containing atmospheres through adsorption of molecular hydrogen on the surface and its absorption within the lattice after dissociation into atomic form. Lastly, internal hydrogen embrittlement, in contrast, takes place in the absence of a hydrogenated atmosphere and is brought about by hydrogen that has entered the lattice during processing or fabrication of steel.

Materials that can be used for hydrogen applications are brass and copper alloys, aluminum and aluminum alloys and copper-beryllium. Nickel and high-nickel alloys as well as titanium and titanium alloys are known to be very sensitive to hydrogen embrittlement.

2.5 HHO GENERATOR

A basic water electrolysis unit consists of an anode, a cathode, power supply, and an electrolyte. A direct current (DC) is applied to maintain the electricity balance and electrons flow from the negative terminal of the DC source to the cathode at which the electrons are consumed by hydrogen ions (protons) to form hydrogen.

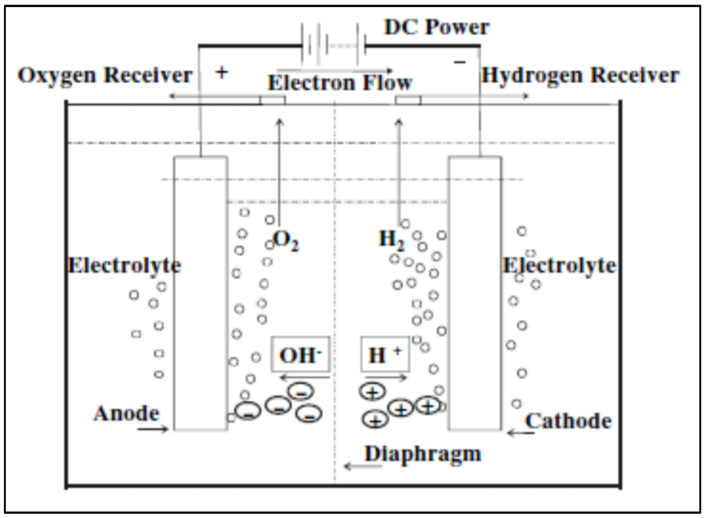

Figure 2.1: A schematic illustration of a basic water electrolysis system

All electrochemical reactions consist of two separate reactions: an oxidation half-reaction occurring at the anode and a reduction half-reaction occurring at the cathode. The anode and the cathode are separated from each other by the electrolyte, the membrane. In the oxidation half-reaction, gaseous hydrogen produces hydrogen ions, which travel through the ironically conducting membrane to the cathode, and electrons which travel through an external circuit to the cathode [5]. In the reduction half-reaction, oxygen, supplied from air flowing past the cathode, combines with these hydrogen ions and electrons to form water and excess heat [5]. These two half-reactions would normally occur very slowly at the low operating temperature. Thus, catalysts are used on both the anode and cathode to increase the rates of each half-reaction. The electrode that works efficient most on each electrode is platinum, but a very expensive material.

CHAPTER 3

METHODOLOGY

Several methods are selected to get the project done smoothly. The project must be done according to the objective and run effectively. The Gantt chart and flow chart are must have item in the methodology. The fuel cell needed to be sketched and the dimensions are to be precise so that right dimension can be selected for the lawn mower and the design must be suitable for the lawn mower so that it is can be fabricate. For the hydrogen generator, it seems that the part is easy to be fabricate and can be conducted for first step. The hydrogen generator would be a small in size and has flexible design and shape so that it can be put anywhere at any necessary lawnmower parts and still can produce hydrogen efficiently. Lastly the plate for the hydrogen generator, the plates can be fabricated with forming machine according to the original design. This design would be different from the usual one since different design produces different results.