An-Najah National University

Faculty of Graduate Studies

Improving the Efficiency of Spark Ignition Engines by Optimizing Injected H_2/O_2 Ratio

By

Shafiq Ra'ed Shafiq Abu Saa

Supervisor

Dr. Abdelrahim Abusafa

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This Thesis was defended successfully on 29/7/2021 and approved by:

Defense Committee Members	**Signature**
• **Dr. Abdul Rahim Abu Safa / Supervisor**	…………
• **Dr. Mahmoud Assad / Internal Examiner**	…………
• **Dr. Ahmed Abu Hanieh / External Examiner**	…………

Dedication

To my father ….

To my mother ….

To my wife ….

To my brothers and sisters ….

To all friends and colleagues ….

To everyone who works in the field ….

I dedicate this work.

Acknowledgement

I would sincerely thank all those who helped me during the period of this work.

My deep gratitude to my beloved family, especially my wife who believed in what I have and my ability to succeed, my mother's support for most of my life.

I would like to thank my supervisor Dr. Abdelrahim Abu Safa for giving me the chance to work with him, and for his continuous support and permanent advice.

I would like to thank my friends for their permanent support to me.

Finally many thanks to my colleagues.

الإقرار

أنا الموقع أدناه، مقدم الرسالة التي تحمل العنوان:

Improving the Efficiency of Spark Ignition Engines by Optimizing Injected H_2/O_2 Ratio

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Declaration

The work provided in this thesis, unless otherwise referenced, is the researchers own work, and has not been submitted elsewhere for any other degree or qualification.

Student's name: **اسم الطالب:** شفيق رائد شفيق أبو صالح

Signature: **التوقيع:**

Date: **التاريخ:** ٢٩/٧/٢٠٢٠

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List of Abbreviations

TSI	Turbocharged Stratified Injection
TDI	Turbocharged Direct Injection
NO_X	Nitrogen Oxide
SO_X	Sulfur Oxides
CO	Carbon Monoxide
CO_2	Carbon Dioxide
MAF	Mass Air flow
MAP	Manifold Absolute Pressure Sensor
TPS	Throttle Pressure Sensor
PD	Prolusion Depot
NaOH	Sodium Hydroxide
KOH	Potassium Hydroxide
NaCl	Sodium Chloride
LHV	Lower Heating Value
RPM	Revolution Per Minute
HC	Hydrocarbon
VOC	Volatile Organic Compound
EPA	Environmental Protection Agency
EGR	Exhaust Gas Recirculation
SCR	Selective Catalytic Reduction
EVAP	Evaporative Emission Control
BDC	Bottom Dead Centre
TDC	Top Dead Centre
TDS	Total Dissolved Solids
IC	Internal Combustion
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
N_2O	Nitrous Oxide
N_2O_3	Dinitrogen Trioxide
N_2O_4	Dinitrogen Tetroxide
N_2O_5	Dinitrogen Pentoxide
HNO_3	Nitric Acid
H_2SO_3	Sulfurous Acid
ECTS	Engine Coolant Temperature Sensor
IC	Internal Cobustion
HHO	Hydrogen-Hydrogen-Oxygen

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Abstract

In this thesis, focus will be placed on increasing the engine's efficiency as well as reducing the proportion of exhaust gases by saturating the oxygen in the air entering the engine. After analyzing the air flow sensor (MAF) reading, the correct air-fuel ratio has been modified using ECM program to ensure that there are no knocks. This was done to prevent any interference in the readings of the sensors responsible for monitoring the efficiency of fuel combustion, such as the Lambda sensor. This procedure was used to increase the combustion efficiency and to alleviate the harmful exhaust gas concentration (CO, CO_2, VOC, NO_X). Hydrogen and oxygen were obtained through an alkaline cell that separates oxygen and hydrogen from the water using electrical separation, where the cell is fed with a vehicle voltage of 13.5 volts and a sodium hydroxide solution is added to catalyst the water to separate. The two gases pass separately through one-way valves that are controlled by a microcontroller to injected appropriate amount of hydrogen and oxygen according to the number of engine revolutions (RPM). Results were monitored using several devices such as (VCDS, DELPHI) that were used to measure sensors output voltage, engine torque and NO_X concentration, in addition to using devices to measure exhaust gas concentration.

AS8700A (Air quality detector) and ECM Titanium program were also used to reduce the amount of fuel injected into the engine to ensure that no disturbances occurred in the engine's operation.

The results show that adding oxygen and hydrogen to the combustion chamber resulted in decreasing the CO, CO_2, VOC, and NO_X concentrations by 8.4%, 5.4%, 13.2% and 20%, respectively.

Chapter One
Introduction

Due to the depletion of fossil fuels, high oil prices, and great environmental damage, which the amount of carbon dioxide polluting the environment in 2019 reached about (40.6 million tons), there is demand and encouragement for car manufacturers around the world to find alternative approaches and methods to increase fuel economy and reduce toxic emissions from internal combustion engines. Where are industrial plants and automobiles are the major source of the exhaust gases[1]. There are many possible attempts to increase the efficiency of engines by using hybrid cars whose principle is by using electricity in addition to fuel, which is the most common method in the world in the modern era. One of the methods used, but was aimed at increasing the efficiency of the engines only, is what is called raising the car's horse power by a special software and replacing the normal engines with turbocharger engines such as TSI and TDI engines, but it did not reduce emissions, and among the methods that he considers a lot of people and companies are the future of cars and the preservation of the environment are electric cars where companies compete to manufacture an ideal electric car that depends on electricity only, where the three conditions will be achieved, which is fuel economy, increase efficiency and reduce exhausts, but the big problem is not the design of the car to work on electricity but rather design power stations to charge the batteries and this will require space and large numbers of stations especially electricity charging cars in addition to the seriousness of dealing with this electricity high-amps for this these remain very far way and may need tens of years to be applied perfectly at the level of the world.

In this study, a special idea of high quality was designed to suit the three desired goals. This idea is carried out by separating the oxygen and hydrogen gas from the water by electrical separation and doing an analysis of the readings of the sensors responsible for air and fuel injection and designing a special control to inject the oxygen and hydrogen in time and the exact quantity. Based on the amount of air entering the engine, monitoring the amount of gases coming out of the exhaust (NO_X, SO_X, CO, CO_2) and monitoring the torque and performance of the engine, where the oxygen will be injected on its own after taking the reading of the air intake sensor (MAF) and the hydrogen will be pumped after reading the amount of fuel and air according to A/F ratio that will be pumped in the combustion chamber.

1.1 Air/Fuel ratio

A stoichiometric combustion involves the presence of 14.7 air atoms for one gasoline atom to ensure that the gasoline atom is completely burnt to obtain the best combustion efficiency and the least possible exhaust gases. The A/F ratio depends on fuel type. It is 14.5:1 for diesel and 34.3:1 for hydrogen. This ratio is given in table 1 for other fuels.

Table 1.1: A/F ratio for hydrogen and other gases [2].

Fuel	Ratio by mass	Main reaction
Gasoline	14.7 : 1	$2C_8H1_8 + 25O_2 \rightarrow 16CO_2 + 18H_2O$
Natural gas	17.2 : 1	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_20$
Propane (LP)	15.67 : 1	$C3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
Ethanol	9 : 1	$C2H_6 + 3O_2 \rightarrow 2CO_2 + 3H_2O$
Methanol	6.47 : 1	$2CH_4O + 3O_2 \rightarrow 2CO_2 + 5H_2O$
Butanol	11.2 : 1	$C4H_{10O} + 6O_2 \rightarrow 4CO_2 + 5H_2O$
Hydrogen	34.3 : 1	$2H2 + O2 \rightarrow 2H2O$
Diesel	14.5 : 1	$2C_{12}H_{26} + 37O_2 \rightarrow 24CO_2 + 26\ H_2O$
Methane	17.19 : 1	$CH_4 + 20_2 \rightarrow CO_2 + 2H_2O$
Acetylene	13.26 : 1	$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$
Ethane	16.07 : 1	$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
Butane	15.44 : 1	$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$
Pentane	15.31 : 1	$C5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

The efficiency of the engine combustion chambers almost in the range of from 30%-45%, and it can be increased by development of engines over the past few decades after the addition of sensors such as (MAF , MAP, LAMBDA ,TPS) to obtain the A/F ratio stoichiometric that according to the amount of air inside the engine to get the highest of efficiency possible in internal combustion of the engine and then the engines of turbocharged stratified injection (TSI) and turbocharged Direct Injection (TDI) which is based on air pressure and cool it before inserting it into the engine for higher power at the same amount of fuel .

$$\text{Efficincy} = \frac{Workdone}{heatabsorbed} \qquad 1.1$$

In this research will try to increase efficiency by increasing the concentration of oxygen in the air before entering the engine to increase the energy that can be obtained from the same amount of fuel and spray the hydrogen in small quantities not stored to Prolusion Depot (PD) Fuel. Oxygen and hydrogen will be obtained through the separation of oxygen and hydrogen from water at process called (HHO). During electrolysis process, a direct current is passed through water after addition of an electrolyte (e.g. NaOH, KOH and NaCl) which renders the solution electrically conductive. The resulting ionisation reactions culminate in the decomposition of water into hydrogen and oxygen[3].

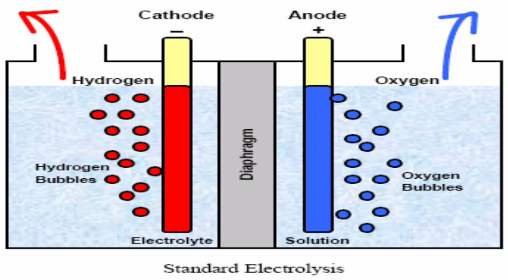

Figure 1.1: Oxy-hydrogen electrolysis [4].

A mixture of hydrogen and oxygen is produced through water decomposition by electrolysis as the name suggests, oxy-hydrogen gas is a mixture of hydrogen (H_2) and oxygen (O_2) gases bonded in a 2:1 ratio in which the "magnecules" of hydrogen (H2) are bonded with alone oxygen (O) atom.

$$2H_2O(l) = 2H_2(g) + O_2(g). \qquad 1.2$$

This fuel contains high calories which when burned produces 241.8 kilojoules of energy (LHV) per mole of H_2 burned. The minimum energy required to ignite such a fuel requires only 20 micro joules, which at normal atmospheric pressure auto ignites at about 570 ^{O}C. The necessary condition for the fuel to burn is to have the hydrogen content in between 4% and 95%. As Hydrogen is being burned, there is no residual hydrocarbon. Oxy-hydrogen gas which is being highly diffusive and homogenous; is very advantageous in fuel to air mixture and due to low density, the safety in case of leakage is high [5].

The required amount of H_2/O_2produced by an alkaline water electrolyser is generally consumed simultaneously by the engine. The high diffusion coefficient of hydrogen improves the homogeneity of the combustible mixture. The flame speed of hydrogen is higher than gasoline, so using a small amount of $H_2$and O_2as additional fuel improves combustion efficiency.

The experimental work will depend on the separation of oxygen and hydrogen gas separately and not as a mixture. The electrolysis of water is the decomposition of water (H_2O) into oxygen gas (O_2) and hydrogen gas (H_2) due to an electric current passing through the water. The generated amount of hydrogen is twice the amount of oxygen, and both are proportional to the total electrical charge that was sent through the water, and the resulting ionisation reactions culminate in the decomposition of water into hydrogen and oxygen. The controller controls all the valves will demand before entered for combustion chambers. The cell is fed from the engine generator, and the controller should keep 12 volts and more than 2A amps which are needed for the separation process and to keep the alternator load less than 80%. The relation between cell current and voltage with the production rate of HHO gases is given in figure 1.2

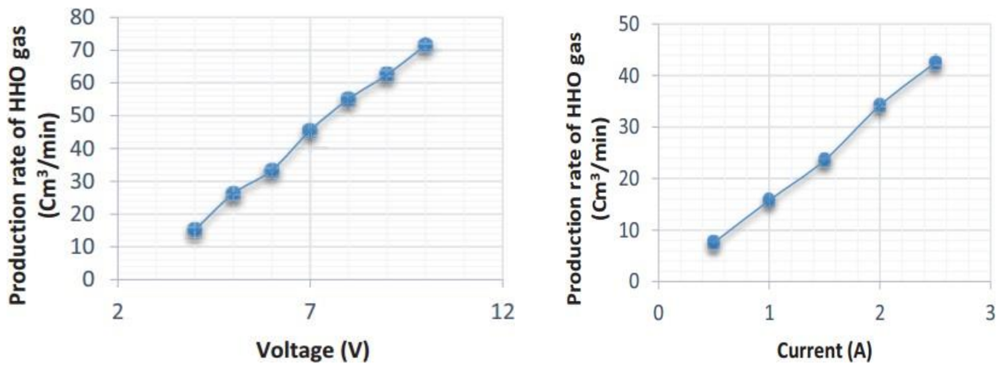

Figure 1.2: Relationship between current and voltage with production rate of HHO gases in oxy- hydrogen cell [6].

1.2 Problem Statement

The environment suffers from an increase in toxic gases that harm it and lead to global warming and other effects that will harm nature, human, animal and plant life. Studies in 2019 indicate that the concentration of carbon dioxide (CO_2) gas has reached 407.8 parts per million and is increasing, due to the lack of commitment by countries in their industrial sectors in taking measures to reduce emissions and not to use clean energy. As a result of previous attempts to separate oxygen and hydrogen in the form of a compound from water (HHO), but as a result of this separation and their introduction into the combustion chambers continuously and without calculating precise amounts for each RPM, this caused vibrations in the engine's work, in addition to the great risk at low engine speeds, despite the literature and previous experiences to use Hydrogen as an alternative fuel for engines to reduce exhaust gases, but despite this, the performance and efficiency of the engine was not maintained [7] .

1.3 Objectives

The main objective of this work is to obtain (experimentally) the optimum ratio of O_2/H_2 to maximize engine efficiency and minimize the harmful exhaust gases (NO_x, CO, HC). This objective will be achieved by:

a. Design and construction of electrolysis cell that produces separately H2 and O2 from water.

b. Connecting special controlled valves at the injection lines of fuel and air.

c. Operating a specific gasoline engine (spark ignition engine) at different speed varying the injected oxygen and hydrogen flow rates and engine torque measurement.

d. Measure the exhaust temperature and the harmful exhaust gases (NO_x, CO, HC) in each experiment.

Chapter Two
Literature Review

- Balaji Subramanian and Saleel Ismail have a study on the use of HHO gas in the combustion chambers of engines, where the gas is obtained through electrolysis of water and used as a promising alternative fuel, where HHO gas is prepared by passing a direct electric current through water after adding a water catalyst such as (e.g. NaOH, KOH and NaCl), which makes the solution is a good conductor of electric current, as the use of gas as fuel increases engine torque and reduces the emission of toxic gases from the exhaust (NOx, CO, HC and CO_2)[1].

- Ammar A. Al-Rousan has a study on introducing HHO gas into the intake manifold in gasoline engines to increase combustion efficiency and reduce fuel use, which reduces pollution caused by exhaust gases. During the electrical separation of water, which is simple and easy to build at a low cost of not more than 15 dollars [8].

- Mohamed M. EL-Kassaby studied the effect of hydroxide on gasoline engines[9]. Where the H cell was designed and optimized to produce the maximum amount of HHO gas, where he was concerned with the number of plates, the distance between them, the type and quantity of the potassium hydroxidecatalyst(KOH) and sodium hydroxide(NaOH), the CO, HC and NOx emissions were measured using TECNO TEST exhaust gas analyzer TE488. While the HHO gas maximum productivity of the cell was 18 litter per hours when using 2 neutrals plates with 1 mm distance and 6 g/L of KOH and 10% increment in the gasoline engine thermal efficiency, 34% reduction in fuel consumption, 18% reduction in CO, 14% reduction in HC and 15% reduction in NOx.

- Sa’ed A. Musmar and Ammar A. Al-Rousan have a study about the effect of HHO gas on combustion emissions in gasoline engines [1]. Factories and cars are the main sources of exhaust gases. As they use fossil fuels as a source of energy. Emissions are simply the combustion residue leaving the engine. Emission testing is usually performed with a probe in the exhaust stream. Emission tests were performed with engine speed changing. The results showed that nitrogen monoxide (NO) and nitrogen oxides (NOX) were reduced to approximately 50% when using a mixture of HHO, air and fuel. Moreover, the carbon monoxide concentration was reduced to about 20%. A decrease in fuel consumption between 20% and 30% has also been observed.

- PierpaoloPolverin et.al They studied the production of oxygen and hydrogen through the electrical separation of water and adding it in small quantities with fuel in gasoline engines to save fuel and reduce gases emitted from the exhaust and to achieve the highest efficiency. They recommend the introduction of intelligent logic control to control the appropriate operating conditions [10].

- Yasin Karagöz et al. Studied Studied the effect of hydrogen on car exhaust emissions and the performance of gasoline engines, and as a result, oxygen decreased at high speeds and as a result of the high flame temperature and the speed of hydrogen combustion, to the high temperature of the cylinders, which leads to engine damage in addition to the increase in nitrogen oxide emission as a result of lack of oxygen, high engine temperature and lack of oxygen [11].

- Cheolwoong Park et. al. Research on the effect of adding hydrogen to internal combustion engines that run on fuel to reduce fuel use to a minimum without causing a backfire, where the experiment was conducted at different speeds on several engines, the results were an increase in the engine temperature, a reduction in the emission of some gases, and the occurrence of vibrations at low speeds [12].

- PavlosDimitriouet al. Studied of the operation of a hybrid engine powered by hydrogen and diesel [13]. Where dual operation can provide significant performance benefits and reduce carbon-based emissions. The results show a strong relationship between the burning hydrogen and the thermal efficiency of the brakes with the rate of EGR. Higher EGR rates increase temperature and provide improved hydrogen combustion and fuel economy.

- Yu, Xiumin, et al. They have many studies on the effect of adding hydrogen to gasoline engines and observing its effect on exhaust gases in light of weak combustion conditions and at low engine speeds. The hydrogen obtained from a cell that produces hydrogen from water as a result of electrical separation, and as a result of these experiments, the emission of carbon dioxide was reduced. and hydrocarbons with a percentage of 32.2% and .80.4%, respectively, but they increase the engine temperature significantly [14].

- Arjun, T. B., et al. have studied due to the increase in fossil fuel consumption, HHO gas was used to inject additional fuel for gasoline into the combustion chambers [15]. An electric cell was designed to separate the oxygen and hydrogen as a compound of water that is supplied with electricity with a power line from the alternator.The gas is pumped through the manifold ducts and the results show that carbon dioxide and hydrocarbon gases decreased by 18% and 14%, respectively.

It was also deduced from the previous literature mentioned above that there is no research thinking about improving the ratio of oxygen and hydrogen or designing a micro-controller to introduce calculated quantities of gases, and that the engine torque was not measured after modification, while in this research the amount of hydrogen and oxygen was addressed and the appropriate amount was entered At every engine speed in addition to the cell control to ensure the highest efficiency and safety

Chapter Three

Theoretical Background

The internal combustion engines operate on the ideal gas law, raising the temperature of the gas increases the pressure that makes the gas want to expand, the engine contains a combustion chamber with air and fuel being compressed into it and then igniting them to gain heat that allows it to expand to give sufficient energy to move the crank shaft from the four-stroke as given in figure 3.1

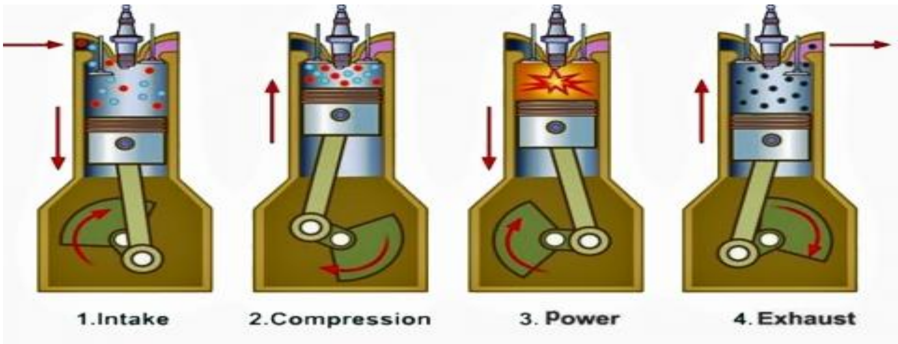

Figure 3.1: Four-stroke engine [16].

The principle of the study is based on separating the oxygen and hydrogen from the water by building an electrolyzer cell, and the separation process is by extracting each gas individually in order to facilitate dealing with them and to avoid any problems and the introduction of each gas of the specified amount to the combustion chambers using a micro-control that controls the injection of gases in order to reduce the amount of emitted gases and increase in combustion efficiency and rationalization of fossil fuel consumption.

3.1 Pollutant Emissions from Internal Combustion Engines

Pollution results from the combustion process in the combustion chamber and in the exhaust stroke, resulting in the exit of gases from the exhaust manifold (CO, CO_2, NO_X, SO_X, VOC, HC) in large quantities that pollute the environment and harm the human being.

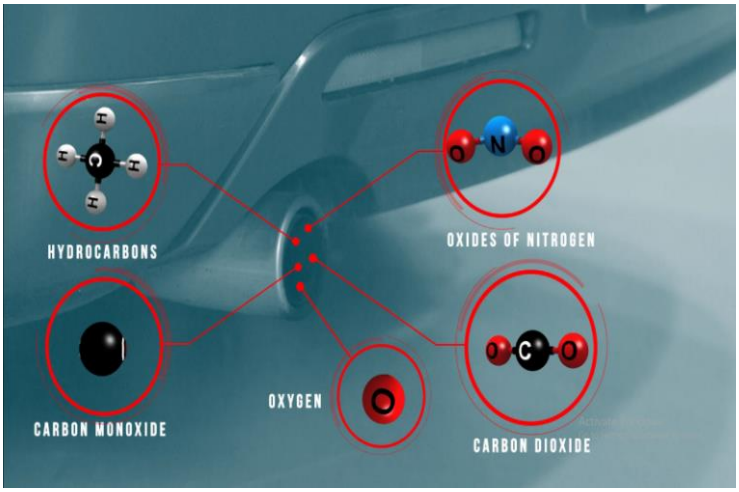

Figure 3.2: Exhaust gas emissions of car [17].

3.1.1 Carbon Monoxide (CO)

It is a by-product of combustion that produces the result of partial oxidation of carbon with the rich fuel mixture. The carbon dioxide gas dissolves into CO and O_2 as the amount of carbon monoxide increases with the increase in the richness of the fuel due to the degradation of the combustion process and low burning temperature that allows the dissolution of carbon dioxide [18].

3.1.2 Oxides of Nitrogen (NO_x)

Oxides of Nitrogen are present in the atmosphere due to human industrial activities and the fuel combustion process. It includes several compounds such as nitric oxide(NO), nitrogen dioxide(NO_2), nitrous oxide (N_20), dinitrogen trioxide(N_2O_3), dinitrogen tetroxide (N_2O_4), dinitrogen pentoxide (N_2O_5), nitric acid (HNO_3). However, the most harmful is NO_x, which refers to NO and NO_2 [19].

3.1.3 Hydrocarbons (HC)

Produced from partial oxidation of fuels (incomplete combustion) or fuel leaks to the environment and is considered a subset of the emissions of volatile organic compounds(VOC), HC concentrations are divided into methane and hydrocarbon emissions [19]. Where the types of HC are divided into two types: evaporative HC and HC combustion.

- Evaporative HC has nothing to do with the combustion of fuel in the combustion chamber, but rather is caused by the volatilization of fuel particles from the fuel tank or through the leakage of fuel pipelines from the tank to the engine.

- The combustion HC is formed as a result of the incomplete combustion of the fuel particles in the combustion chamber, which will come out of the exhaust in the form of volatile particles.

3.1.4 Particulate Matter (PM)

It contains particulate emissions from primary carbon, HC, volatile organic materials, and sulfur compounds. The emissions are very small carbon particles that are solid in diesel engines higher than gasoline engines [20]. Soot formation results from incomplete combustion of hydrocarbons and from the burning of lubricating oil, Particulate formation occurs in three main stages during and after the combustion period as described below:

- Nucleation mode: It consists of condensation of volatile organic matter, sulfur compounds and combustion process compounds, in this phase the total mass of the formed particles is only a fraction of the final mass but their number is very large.

- Accumulation mode: At the peak of the formation of nuclei, the number of particles reaches a value. Collisions between the particles become repetitive, as the two particles collide, unite, increase sedimentation, and the number of particles begins to decrease. In this phase, the particle size and mass increase.After the surface growth stops, the particles continue to increase by one assemble in groups or chains with dynamic diameters greater than 50 nm.

3.1.5 Sulfur Oxides

Sulfur oxides are compounds of sulfur, oxygen moleculesand sulphur dioxide (SO_2) resulting from burning coal and fossil fuels in industrial processes and in natural sources volcanic eruptions, but burning of coal and compounds is the main contribution to its emission. It is an odorless gas that can be distinguished from the smell only and dissolves in water to form sulfuric acid (H_2SO_3).In internal combustion engines, Sox is formed as a result of incomplete combustion of fuel particles as a result of miss fire or fault in Air Fuel ratio.

3.2 Pollution exhaust emissions reduction technologies

As a result of the increase in the number of cars in the world and the increase in waste gases that harm the environment, car manufacturers, by order of the Environmental Protection Agency (EPA), have adopted technologies to reduce these exhausts and these technologies:

3.2.1 Exhaust Gas Recirculation (EGR)

EGR can be used in diesel and gasoline engines, which is a mechanic that is placed after the exhaust manifold is controlled by using an electric or pneumatic vacuum wrap where it pulls gases that guarantee NO_x caused by incomplete combustion of fuel in the combustion chamber, then the EGR returns these gases to a room Combustion again to a internal Combustion again to be fully combusted to reduce the amount of NO_x gas leaving the engine, but it leads to an increase and changes in the formation of PM emissions as a result of the low concentration of oxygen gas in the combustion process [21] .

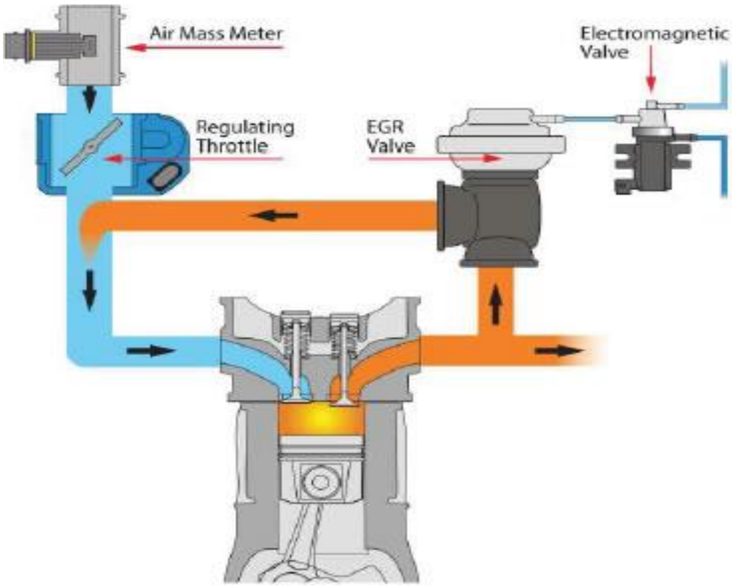

Figure 3.3: Exhaust Gas Recirculation system [22].

3.2.2 Advanced Fuel Injection Systems

It is a higher fuel pressure and smaller injector holes and different angles, which will lead to lower local peaks and temperatures in addition to fuel injection delays will increase the efficiency of the engine and reduce nitrogen oxides (NO_x).

3.2.3 Catalytic Converter

It is made of ceramic and titanium and other materials where the exhaust gases pass through it and in turn it dismantles the toxic gases as it is effective for carbon dioxide and carbon monoxide unlike NO_x and SO_x as it is sometimes it does not work with high efficiency and its efficiency is low very when the engine temperature is low and requires regular maintenance and replacement every 80,000 km [23].

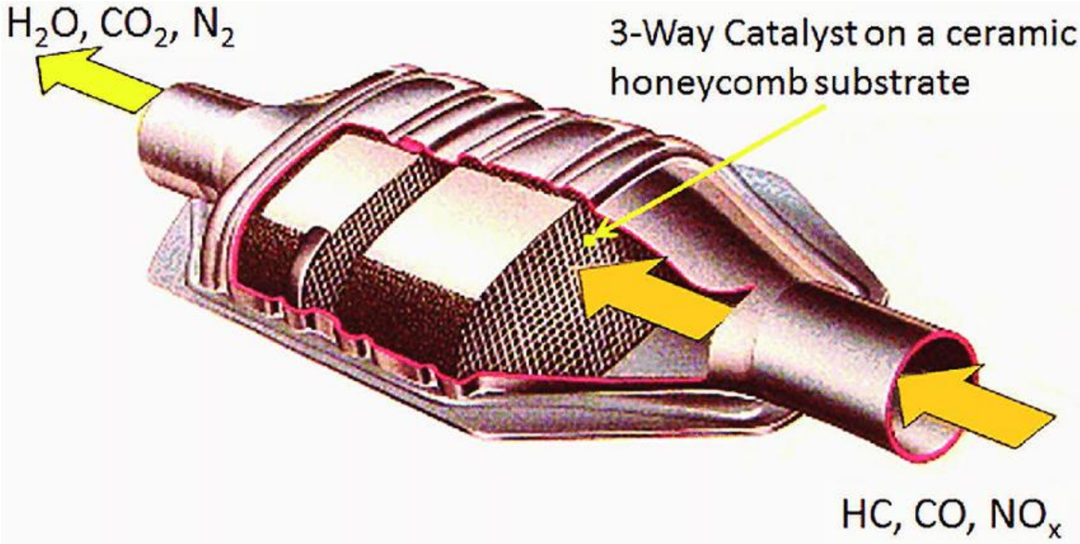

Figure 3.4: Catalytic converter technology [24].

3.2.4 Selective Catalytic Reduction (SCR)

NO_x gas emissions can be reduced by using selective catalytic reduction (SCR) and by adding urea (CO $(NH_2)_2$) to the exhaust gases. Urea hydrolyses and releases NH3 and CO2 as the following equation:

$$CO\,(NH_2)_2 + H2O \rightarrow CO_2 + 2\,NH_3 \qquad 3.1$$

Where NH3 reacts with NO_x and O_2 to yield H_2O and N_2:

$$4\,NO + 4\,NH_3 + O_2 \rightarrow 4\,N_2 + 6\,H_2O \qquad 3.2$$

$$NO + NO_2 + 2\,NH_3 \rightarrow 2\,N_2 + 3\,H2O \qquad 3.3$$

$$2\,NO2 + 4\,NH_3 + O2 \rightarrow 3\,N_2 + 6\,H_2O \qquad 3.4$$

The efficiency of the SCR ranges between 60-80%, but it operates at low temperatures 180 to 200 ° C which makes a problem when the exhaust temperature rises higher than that, its efficiency becomes low [25].

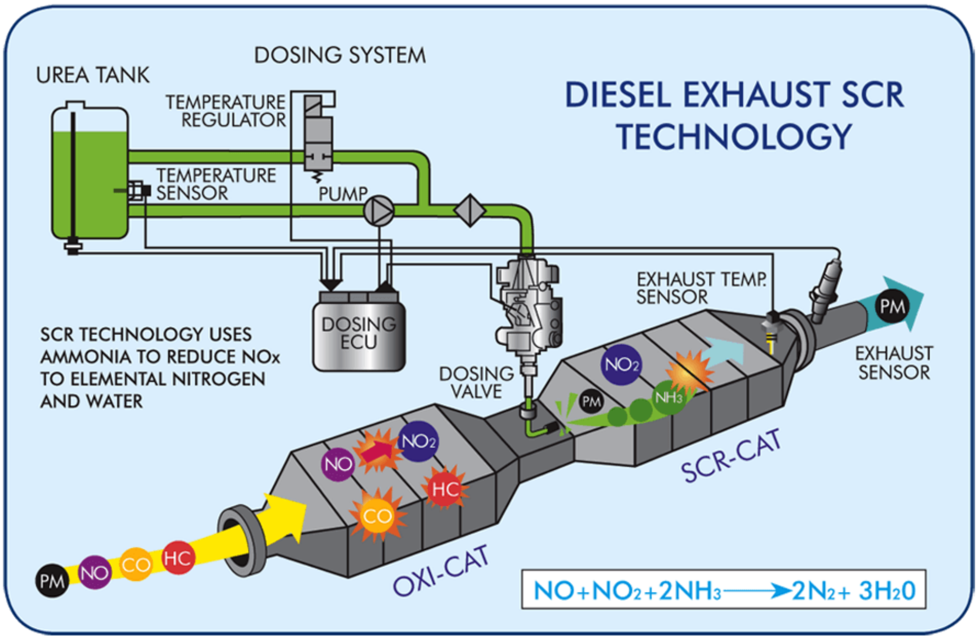

Figure 3.5: Selective catalytic reduction technology [26].

3.2.5 Evaporative Emission Control (EVAP) System

The evaporative emission control system prevents the fuel vapors from leaking into the atmosphere because the fuel vapors contain a large amount of hydrocarbons that make up the smog when they interact with the obsessive and sunlight as the car can pollute the atmosphere 24 hours a day without even running it.EVAP contains a box connected to the fuel tank with tubes containing 0.5-1 kilograms of activated charcoal that acts as a sponge as it absorbs the evaporated fuel and vaporizes it in the intake manifold to be burned.

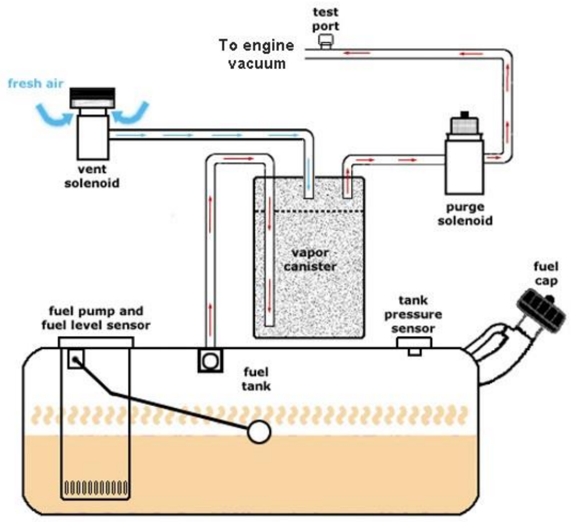

Figure 3.6: Evaporative Emission Control (EVAP) System [27].

3.2.6 Efficiency of engine

The efficiency of the engine represents the biggest challenge among the car manufacturers, as most of the efficiency of the engine comes out in the form of heat to be cooled, in addition to the heat of the outgoing gases as given in figure 3.7.

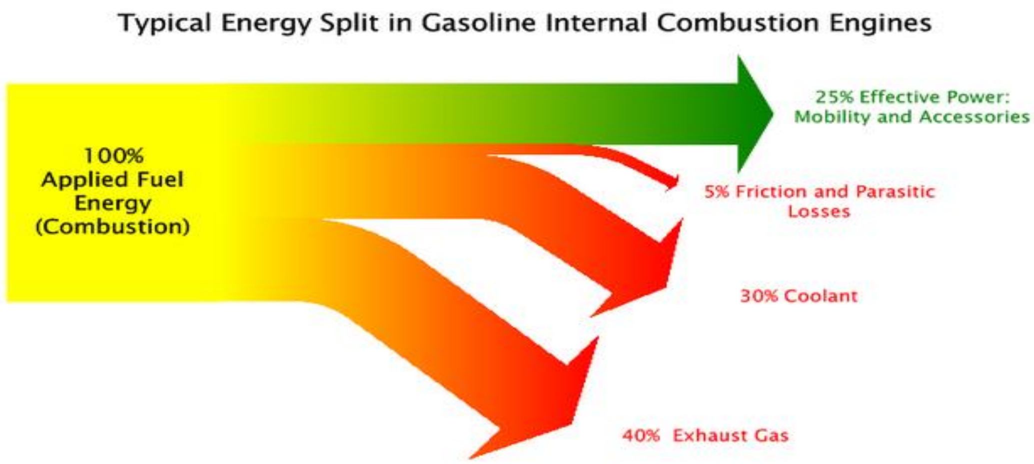

Figure 3.7: typical energy split in gasoline internal combustion engines [28].

There are many attempts to raise the efficiency of the combustion engine, such as adding nitrous gas and increasing the volume of combustion chambers, but all of them negatively affected the shelf life of the engine, the introduction of hydrogen gas and oxygen to the engine in exact quantities does not affect the work of the engine because the oxygen percentage will not exceed 24% in the air, and this percentage will not be effective on the engine, and hydrogen that will be injected instead of a certain amount of fuel in precise quantities and at the optimal time by one-way solenoid valve controlled by a micro-controller that determines the quantities through the signals it receives from the sensors responsible for measuring the amount of air Break the engine.

3.4 Increased engine efficiency technologies

Several techniques have been used to increase the combustion efficiency of the engine. The most important of these technologies:

3.4.1 Air-Fuel sensors

The principle of operation of the engine is based on burning fuel and air in the combustion chamber of 14.7: 1 air fuel ratio, and the amount of fuel required to be pumped into the combustion chamber is determined by several sensors responsible for sensing the amount of air entering the engine and the most important:

- **Mass Air Flow sensor (MAF):** It is a sensor that measures the amount of air flow passing through the air filter to the throttle gate and sends a signal to the car's engine in the form of a voltage by the principle of heating the wire in it where the greater the amount of air passing through it will cool the wire to a lower temperature and thus a higher voltage will pass to the wire to be Heat it again to reach the temperature that it was on. And through this voltage that was pulled, the engine control module (ECM) knows the amount of air passing through and thus determines the amount of fuel needed to be entered into the internal combustion and the sensor reading is in grams.

Figure 3.8: Mass air flow sensor [29].

- **Throttle position sensor(tps):** It is a sensor that measures the angle of opening the gate according to the amount of driver pressure on the fuel exchange and sends this signal to the engine control module to determine the position of the engine if it is in the case of acceleration or deceleration or in the case of idle speed, for example if the angle is small, the computer knows that in the case of idle speed is fed the sensor with 5 volts and the computer receives a signal from 0-5 volts where if the gate is closed the computer receives a signal in the 0.5volt and if the gate is fully open it receives a 4.5 volt signal.

Figure 3.9: Throttle position sensor [30].

- **Lambda sensor (O_2):**It is called an oxygen sensor that exists before and after catalytic converter and its function is to measure the percentage of oxygen after the combustion process to determine if the mixture is rich or lean, and it sends information as voltage between 0-1voltthen A/F ratio is stoichiometric if the voltage is 0.45 volt, but if it is higher than 0.45 volt that means fuel percentage is high (rich mixture). Accordingly, the control module reduces the amount of fuel, and if it is less than 0.45 volt, the oxygen content is high (lean mixture). The computer increases the fuel percentage to reach the stoichiometric combustion.

Figure 3.10: lambda sensor [31].

3.4.2 Turbo and Supercharger

Turbo-charging device compress the air and then enters it into the combustion chambers to obtain a higher engine power and is located at the exhaust manifold and works through the exhaust gases caused by the exhaust stroke which is a lost energy for the engine as it is used to rotate the turbo butterfly, where it is controlled by valve which is opens or closes the road to enter the gases to the turbo according to the exhaust gases pressure and the engine RPM when the way is opened for the gases to rotate the turbo butterfly on the opposite side there is a butterfly connected to shaft with the first butterfly to compress the air before entering the engine as in TSI and TDI engines [32].

Figure 3.11: Turbo-charging device [33].

3.4.3 Compression ratio

Compression ratio is the volume of the combustion chamber cylinder when the piston is at the bottom (BDC) and the volume of the combustion chamber cylinder when the piston is at the top (TDC) where combustion efficiency can be improved by increasing the compression ratio as the air pressure in the combustion chamber increases, you get a more powerful explosion in addition to saving In fuel consumption, for example, if the compression ratio were increased from 1:9 to 1:10 compression, there would be an increase in the combustion efficiency and saving about 6 % of the fuel consumption.

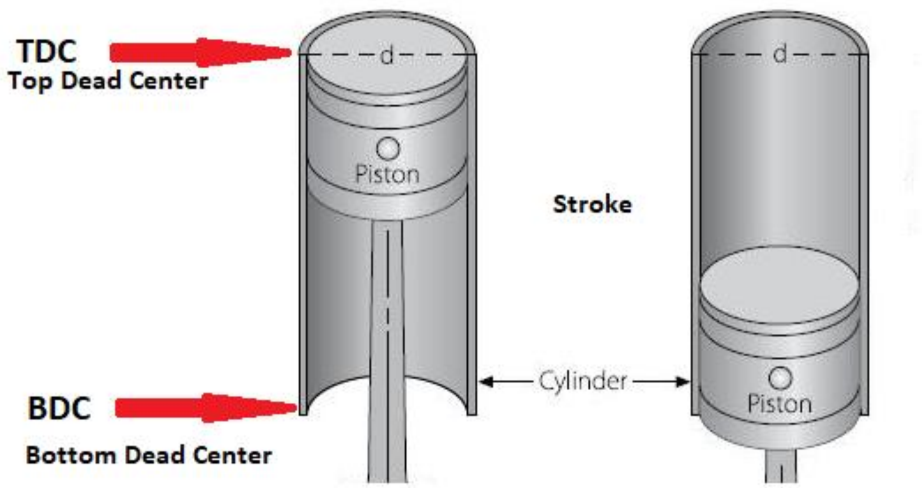

Figure 3.12: Compression ratio for gasoline and diesel engines [34].

3.4.4 Nitrous oxide system (NOS)

The nitrous oxide molecules consist of two nitrogen atoms and one oxygen atom, which is equivalent to 36% oxygen. Increasing the concentration of oxygen in the air will lead to an increase in the cooler air and allow burning more fuel and an increase in flame and thus an increase in HP. But despite all that, the increase in the percentage of oxygen and the reduction of nitrogen will lead to an increase in the heat caused by the explosion and the inability of nitrogen gas to absorb this amount, which may cause engine damage.

3.4.5 Number of intake and exhaust valves

The four-stroke internal combustion process requires a mixture of air and fuel to produce a certain amount of energy with a certain efficiency as the valves allow entry and exit of air from outside to the combustion chambers according to the appropriate ignition timing, and this occurs in the intake and exhaust stroke. Fast entry and exit of air will increase the combustion speed, which will increase the combustion efficiency of the engine Therefore, the more the number of valves that higher the efficiency.

3.5 Thermodynamics of water electrolysis

Electrolysis is the splitting apart of water molecules into hydrogen (at the cathode) and oxygen (at the anode) when a direct current is passed between two electrodes submerged in water. Potassium hydroxide (KOH) and sodium hydroxide (NaOH) solutions are typically used as electrolytes to reduce the resistance of water and thus increase the current flow across the electrodes and speed up the reactions[35]. Possible difference that will be applied through the electrodes depends on the amount of gas generated per unit of time. The reactions that occur in the electrodes are given below:

At cathode: $2H{+}O + 2e/H{+} + 2OH$ 3.5

At anode: $4OH/O_2 + 2H_2O + 4e$ 3.6

Overall reaction: $2H_2O/2H_2 + O_2$ 3.7

3.5.1 Types of Electrolyzers

1. Alkaline electrolyzers

is one of the easiest ways to produce oxygen and hydrogen from water. The cell is made of two anode and cathode poles. Each electrode is a solid metal or several monolithic cells where water dissolves and hydrogen is created at the cathode and oxygen collects from the anode in a ratio of 2:1, that is, each hydrogen atom is produced, corresponding to one oxygen atom. Alkaline electrolyzers contain caustic water solution of potassium hydroxide, sodium hydroxide or sodium chloride as they are used as a catalyst that increases the conductivity of water to facilitate the passage of electrical charges responsible for the dismantling of water molecules.

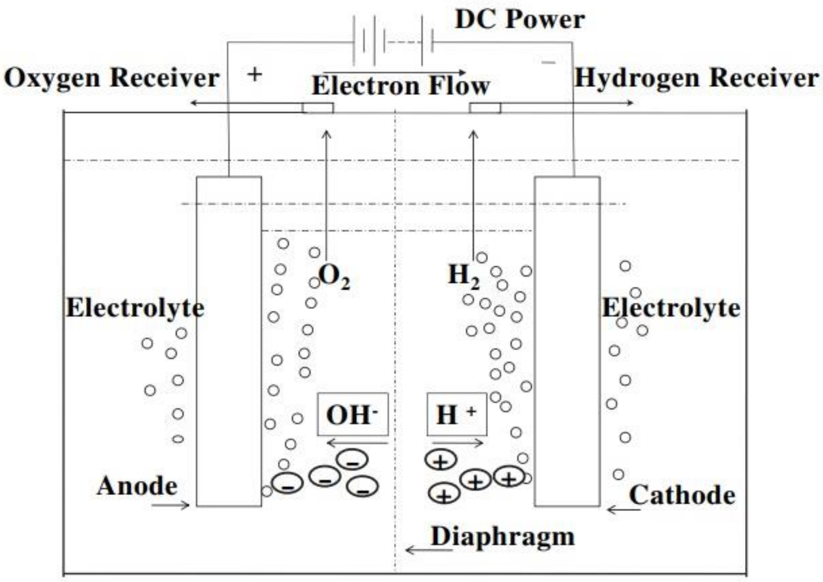

Figure 3.13: Schematic illustration of basic water electrolysis system [36].

2. Solide Oxide Electrolyzers

It is a solid oxide fuel cell that operates in the regenerative mode to achieve hydroelectric analysis by using solid oxide or ceramics to produce oxygen and hydrogen gas and operate at high temperatures which makes it more efficient than alkaline electrolyzes, and it is a number of compact plates with a buffer between each of the two plates and in a closed system as given in figure 3.14

Figure 3.14: Solid oxide electrolyzer [37].

3. Polymer Electrolyte Membrane Electrolysis

Polymeric electrolyte membrane made from the polymer perfluoro sulfonated acid type,is used as an electrolyte and because of its acidic nature expensive noble metal catalysts such as platinum for hydrogen and iridium should be used in the oxygen electrode and anti-corrosion sheets made of titanium are used [38]. The membrane electrolyte can pass a higher current which may be useful in applications requiring a high electrical supply such as in renewable energy installations.

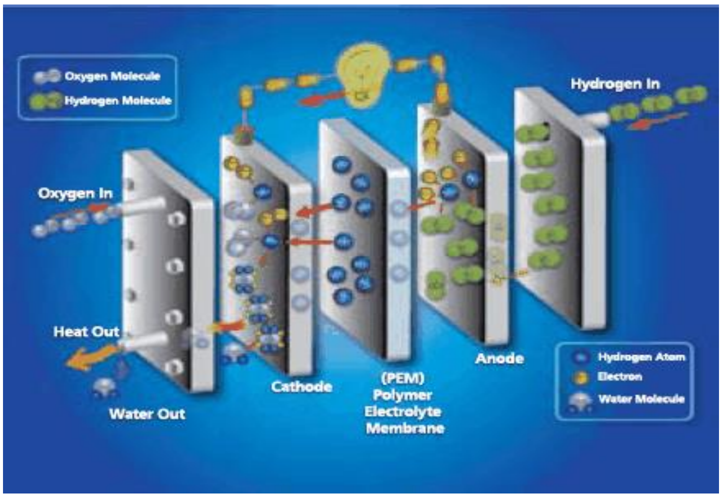

Figure 3.15: Polymer Electrolyte Membrane Electrolysis fuel cell [39].

Chapter Four
Methodology

4.1. General Equipment Setup

The aim of this study is to test the effects of hydrogen and oxygen gases to the combustion chamber of a gasoline engine , the impact of toxic gas emissions and the efficiency of the engine in addition to rationalizing fuel consumption without any side damage to the performance of the engine and its experiment to determine if it was a sustainable and practical solution to reduce fuel consumption and gas emissions from exhaust. A schematic representation of the initial setup that was used during the tests can be seen in Figure 4.1:

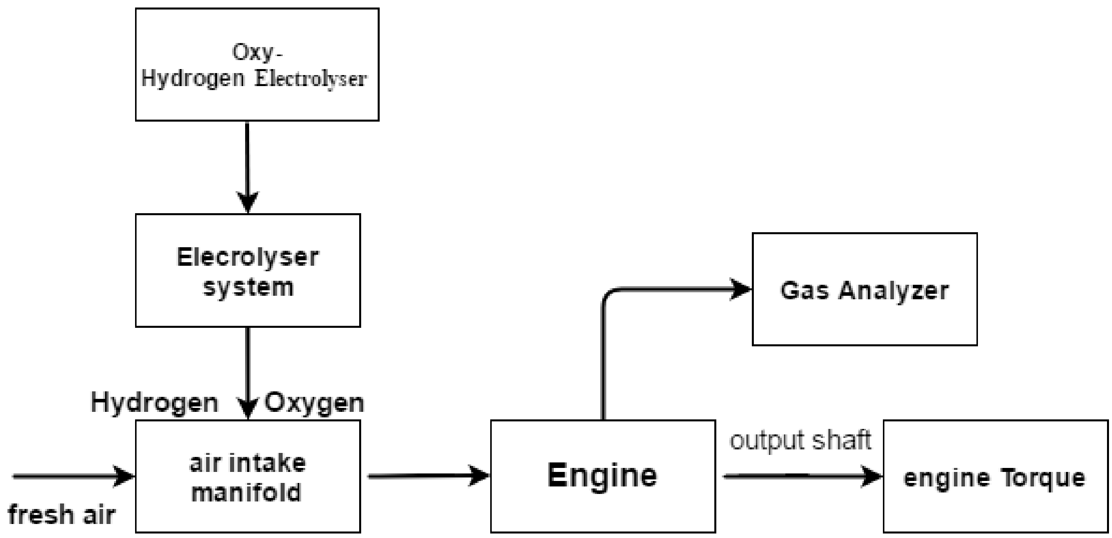

Figure 4.1: General equipment setup schematic.

After the injection of oxygen and hydrogen, all of the following will be recorded:

1. RPM regularity as a result of hydrogen injection as an additional fuel for gasoline.

2. The rate of fuel consumption after adding hydrogen gas and reducing the amount of gasoline that will be pumped into the combustion chamber.

3. Heat resulting from combustion after increasing the oxygen concentration in the air and increasing the bursting strength in the power stroke as a result of burning hydrogen.

4. The effect of increasing the concentration of hydrogen in the air on the amount of exhaust gases coming out of the exhaust and the effect of burning hydrogen on them.

5. The efficiency of hydrogen combustion at different engine speeds

6. Monitor engine torque at different engine speeds after adding hydrogen and oxygen.

4.1.1 Engine characteristics used for test

A car engine was used to test an effect in addition to hydrogen gas and oxygen to the combustion chamber and to monitor exhaust gases, engine performance, and table 1 shows engine specifications.

Table 4.1: Engine specifications.

Manufacturer	Volkswagen
Engine code	ATW
No. of Cylinders	4
Compression Ratio	9.5:1
Air Intake	Natural Aspiration
Capacity	2000cc
Fuel	Petrol
Fuel System	Fuel Injection
Ignition Timing Control	Programmable ECU

This information was obtained by Autodata program. The program contains all the information about any car.

4.1.2 Exhaust gas analysis

Automotive engine testing devices were used to measure the concentration of CO, HC, SO_x, NO_x, CO_2 and O_2 in the exhaust gases (VCDS, launch x431) by taking live readings of the sensors on the exhaust pipes that read the gas concentration.

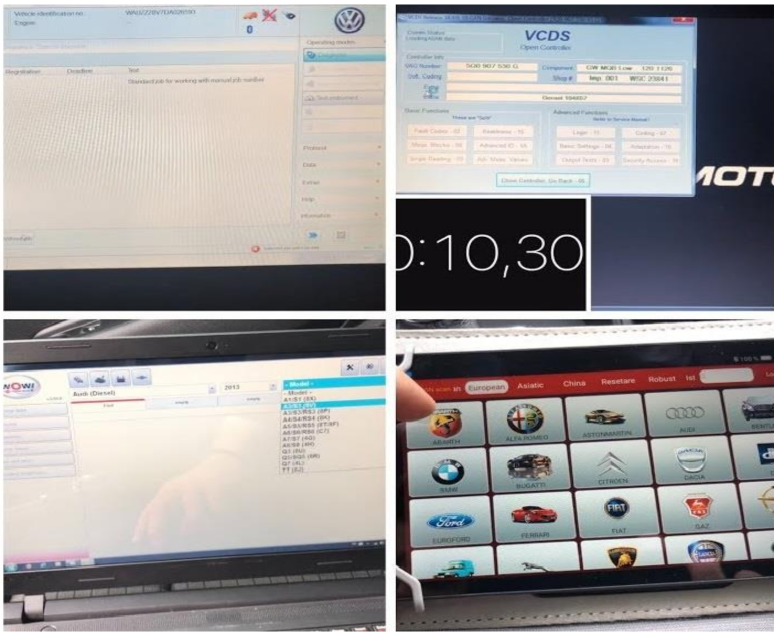

Figure 4.2: Diagnostic devices [40]

4.1.3 Alkaline Electrolyser Cell Feature

Alkaline Electrolyser was used to separate hydrogen and oxygen from water where distilled water and sodium hydroxide (NaOH) were used as a catalyst to increase water conductivity, the aim of reducing electricity consumption and as well as increasing the current density in order to reduce the cost of capital investment [41]. The alkaline cell has several advantages, the most important of them:

1. Simple, does not require complications in the construction of the cell. All that is necessary are two poles and a catalyst for water.

2. It produces large amounts of hydrogen and oxygen easily and safely.

3. The voltage and current can be controlled by the number of plates used at each electrode and by controlling the water conductivity.

4. It does not need high maintenance. It just needs to change the poles.

5. Hydrogen and oxygen can be used directly from the cell when needed without the need to store them.

4.1.4 Alkaline Electrolyser Construction

The alkaline electrolyzer will be built with a unipolar design that consists of two metal electrodes suspended in a U-shaped water pool as given in figure 3.Electrodes will use a cell for each electrode, which each cell consists of 3 plate of stainless steel. The thickness of each plate is 1.2 mm and diameters 4*11cm. All 3 plates will be connected with each through 2 holes between them. Each plate will be given a source of 2.2 volts.

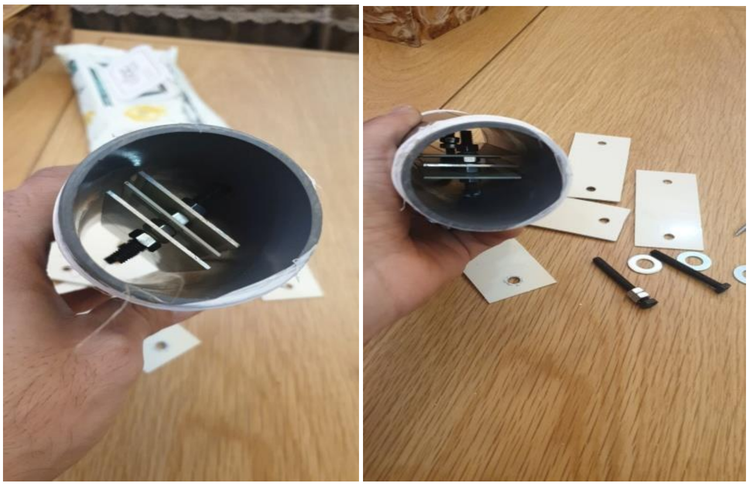

Figure 4.3: Plates of Oxy-hydrogen electrolyzer cell.

When the electrical energy is provided for the electrodes, the hydrogen gas and oxygen are separated and accumulate at the electrodes so that the electrolyzer is designed efficiently, and so each gas is collected separately without mixing between them.

4.1.5 Electrolyser design

The required amount of H_2/O_2produced by an alkaline water electrolyser is generally consumed simultaneously by the engine. The high diffusion coefficient of hydrogen improves the homogeneity of the combustible mixture. The flame speed of hydrogen is higher than gasoline. Using a small amount of $H_2$and O_2as additional fuel improves combustion efficiency [42].

The oxygen is pumped to air intake line to increase the concentration of oxygen in the air through a one-way solenoid valve and hydrogen is pumped into the fuel line before entering combustion chambers through another valve as can be seen in figure 4.4.This process should be controlled by a micro controller which gives all commands to control the combustion process with higher efficiency and save the life span of the engine.

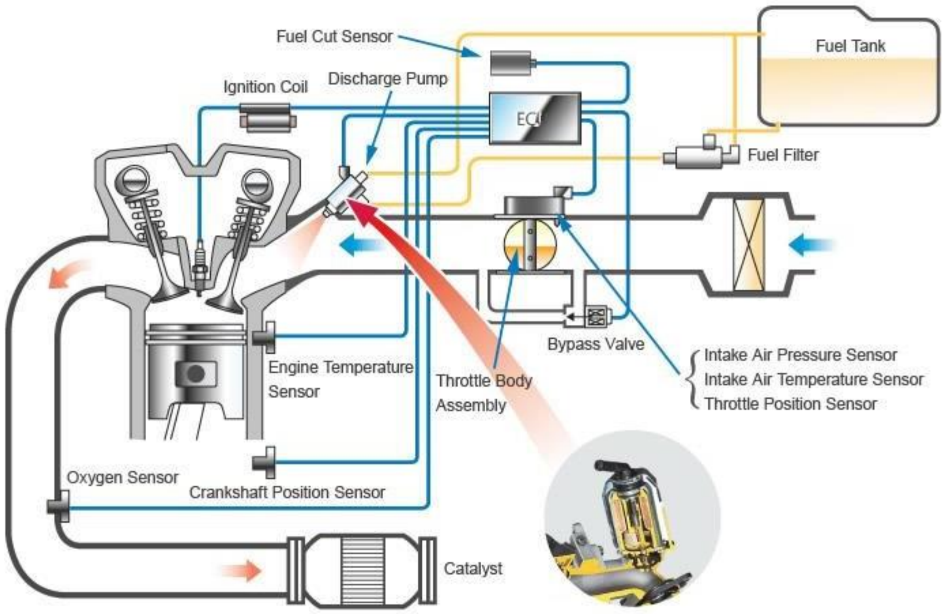

Figure 4.4: Oxygen and hydrogen injection mechanism in internal combustion engine [43].

4.1.6 Other Hardware Components

A realistic system will designed with several components to ensure that the engine works in a highly efficient manner, as the components will be controlled using a micro-controller, and these components are used:

- **One Way Solenoid Valve:** To determine the amount of gases that will be pumped into the combustion chambers based on the orders received from the controller and according to the appropriate time in addition to not returning the gases.

Figure 4.5: One way solenoid valve.

- **Micro Controllers:** To control the work and system of the project in the best sequence starting from the cell responsible for separating oxygen and hydrogen according to the required quantities based on the readings of the sensors responsible for the amount of fuel and air injection such as (MAF), TPS, O2, MAP) and control the opening and closing of valves and warning in the event of a problem Surprise.

- **Filters**: To purify the oxygen and hydrogen from impurities and salts to obtain pure gas that can be used in the combustion process inside the engine combustion chambers**.**

Figure 4.6: Oxy-Hydrogen filter [44].

4.2 Testing Procedures

The following procedures have been followed to test the effect of adding hydrogen and oxygen to the engine:

- Measure engine torque and concentration of the exhaust gases (CO, HC, SO_x, NO_x, CO_2) without adding oxygen and hydrogen

- Analyzing the sensor readings responsible for measuring the amount of air and fuel to determine the amount of oxygen and hydrogen to be entered to the engine and the quantities are controlled by a controller.

- Measuring torque and exhaust gas concentration at different engine speeds after adding hydrogen and oxygen to the engine.

The amount of hydrogen and oxygen that will be produced from the electrolyzer will be ascertained similar to the hydrogen generator and oxygen that was used [45].where the amount of gases flowing is 2:1 for hydrogen and oxygen, respectively.

The electric energy needed to feed the cell will be fed from the car's generator through a wire that extends to the back of the car whose voltage ranges from 13.5-14.5V in addition to a fuse installed on the wire to protect from the occurrence of an overload. The power is controlled by a micro-controller that controls the operation of the system.

The load on the generator will be monitored before adding the system so that the load does not exceed 80 percent to ensure that no overload occurs leading to engine failure. The following steps will be followed to ensure this does not happen:

- Use a wire thickness that is proportional to the current in which the cell will be fed.
- Add a calculated amount of sodium hydroxide to ensure that a certain resistance to water is maintained.
- The cell will operate only when hydrogen and oxygen are needed, which will reduce the load on the generator.

Chapter Five
Experimental Setup

A four-cylinder petrol engine was modified by adding hydrogen gas and increasing the oxygen concentration in the air**.** This was done through an integrated system that was controlled by a microcontroller.

5.1 Oxy-Hydrogen Electrolyzer

The cell that was designed to separate hydrogen gas and oxygen from water is shown in Fig.1. Which 3 plates were used at each electrode.

Figure 5.1: Oxy-hydrogen electrolyzer.

The cell was fed 13.5 volts and the water conductivity was increased by adding sodium hydroxide to determine the current drawn from the battery Table 1 shows the characteristics of the cell

Table 5.1: Characteristics of the oxy-hydrogen cell.

Type of fuel cell	Alkaline Electrolyser
The number of plates at each pole	3
Plate thickness	0.4cm
liter of water	1.125 l
Catalyst	Sodium hydroxide
Voltage	13.5v
Current	2 A
Amount of hydrogen produced	14.8ml/s
Amount of oxygen produced	7.2ml/s

5.1.1 Oxygen and hydrogen production

The amount of oxygen and hydrogen that will be separated from the water will be measured under certain conditions such as temperature and voltages and the amount of sodium hydroxide that will be added to the water to control the conductivity of the water to know the current that will be withdrawn .Water conductivity will be measured using TDS conductivity meter, and it will be an experiment to measure the conductivity until a suitable current is obtained for the desired quantity of oxygen and hydrogen at a certain time, where 165 grams of sodium hydroxide were added to the cell.

Figure 5.2: TDS Conductivity Meter [46].

Then will measure the volume of the separated oxygen and hydrogen using a simple method represented by a numbered tester as in the figure 5.3

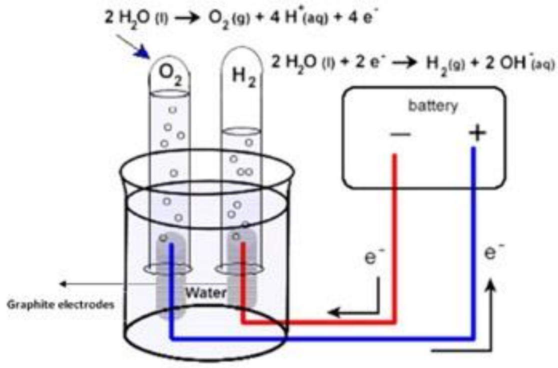

Figure 5.3: Measurement of Gas volumes [47].

Figure 5.4: Volume of hydrogen and oxygen gas.

The volume of gases that was separated from the water was measured using two laboratory tubes, which were filled with water and placed in a water container, and the gas was measured by the amount of water displacement in the tube. As in the figure 5.4

5.2 Analyze the sensor readings

Sensors readings will be analyzed before and after the application of the system to monitor the efficiency of the system and record the results of exhaust gases, fuel consumption and engine torque through the use of a vcds program that reads the engine ECM and other controllers in the car, which is a German device that reads computers (Seat , Audi,vw,Skoda).

Figure 5.5: VCDS device.

5.3 Engine Modification

The engine will adjust the entry of air and fuel, as there will be no strikes in the engine after the introduction of oxygen and hydrogen gas into the combustion chambers. Where the amount of fuel will be reduced as a result of a certain amount of hydrogen by changing the engine computer software map using a program (Ktag) that pulls the engine software and then using a program (ECM titanium) that manipulates the programming map of the engine’s work and the amount of fuel that will be pumped at each specific engine RPM.

5.3.1 Oxy-Hydrogen cell install

The cell was installed in an area close to the engine to reduce the distance from which the gases would travel to the engine, in order to avoid the hydrogen gas from remaining for a long time without use as shown in figure 6.

Figure 5.6: The location of the cell in the vehicle.

5.3.2 Gases Pipeline

The hydrogen gas pipeline and oxygen gas pipeline were installed between mass air flow sensor and throttle position sensor in order to facilitate the entry of gases without obstacles as shown in the figure 5.7.

Figure 5.7: Pipe lying on the air duct of the throttle valve body.

5.3.3 Cell Electricity

The cell was fed with 13-volt electricity from the car's alternator, which charges the battery and feeds the car's systems, as electricity will be delivered to the cell only when the car is running through the use of a relay linked to the alternator as in the figure 5.8.

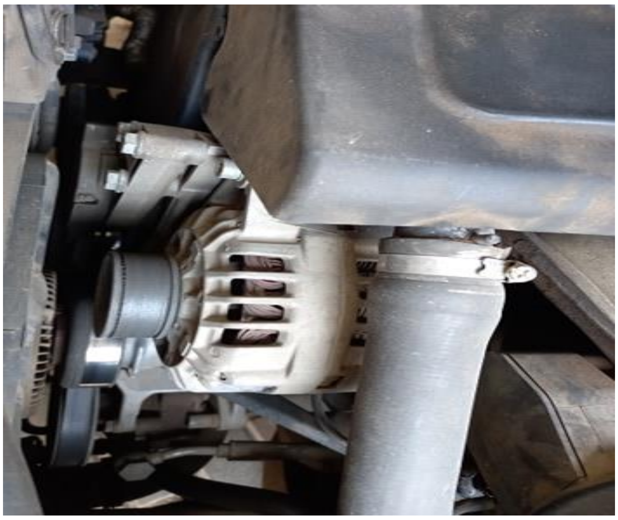

Figure 5.8: Alternator of car.

Arduino microcontrollers were used to control the cell's work and cut off its electricity when needed. It controls the work of solenoid valve responsible for oxygen and hydrogen gas and solenoid valve the expulsion of excess gases that are not needed and to ensure that they are not stored.

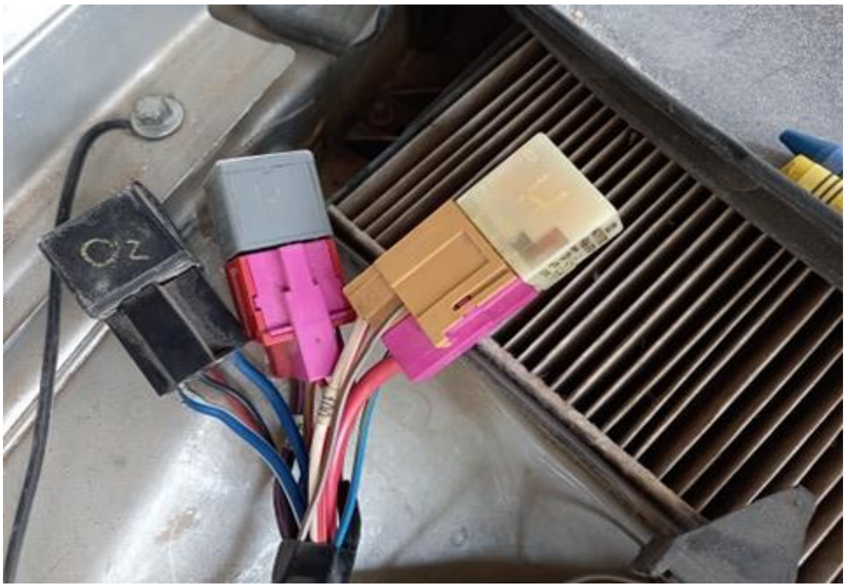

Figure 5.9: Mass air flow wire signal to microcontroller.

Figure 5.10: for oxygen and hydrogen control.

Figure 5.11: One way valve solenoid.

Figure 5.12: Oxygen and hydrogen pipes.

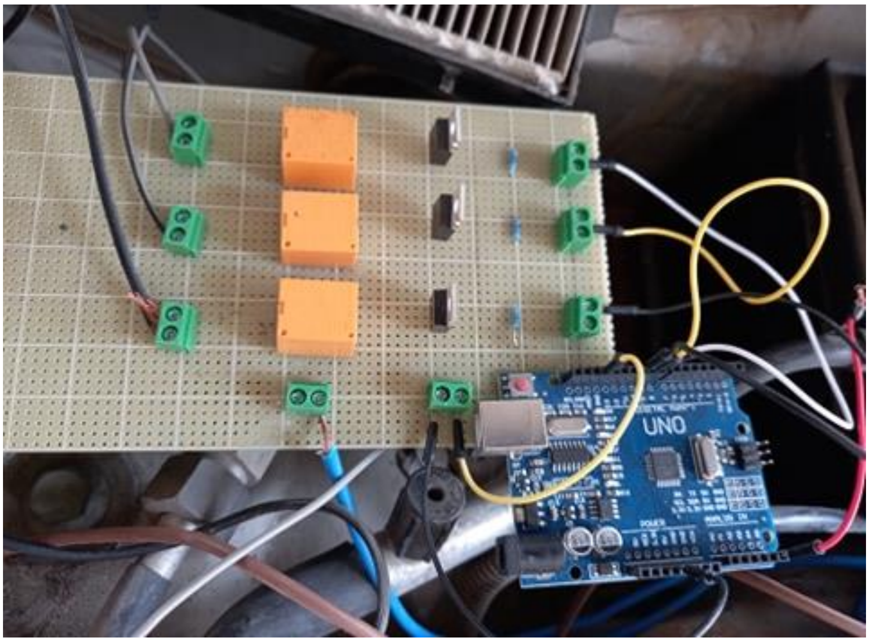

Figure 5.13: Control panel for oxygen and hydrogen entry and exit.

5.4 Exhaust Gas Monitoring

The gases resulting from combustion will be monitored in the combustion chamber (NO_X, CO_2, CO) before installing the cell. Some gases will be monitored using the VCDS program such as (NO_X) and other gases will be measured using devices such as (CO) that we will measure the concentration of gases through the exhaust where they will be measured at RPM is different.

Figure 5.14: Carbon monoxide meter (AS8700A) [48].

In addition to air quality detector, which measures the (CO_2, VOC, HC) gases emitted from the exhaust.

Figure 5.15: Air quality detector [49].

5.5 Final experimental setup design

The cell was designed after several experiments to maintain the efficiency of the engine's work in addition to adding everything necessary such as microcontrollers and valves and using devices to measure the gases emitted from the exhaust as shown in the figure 5.16.

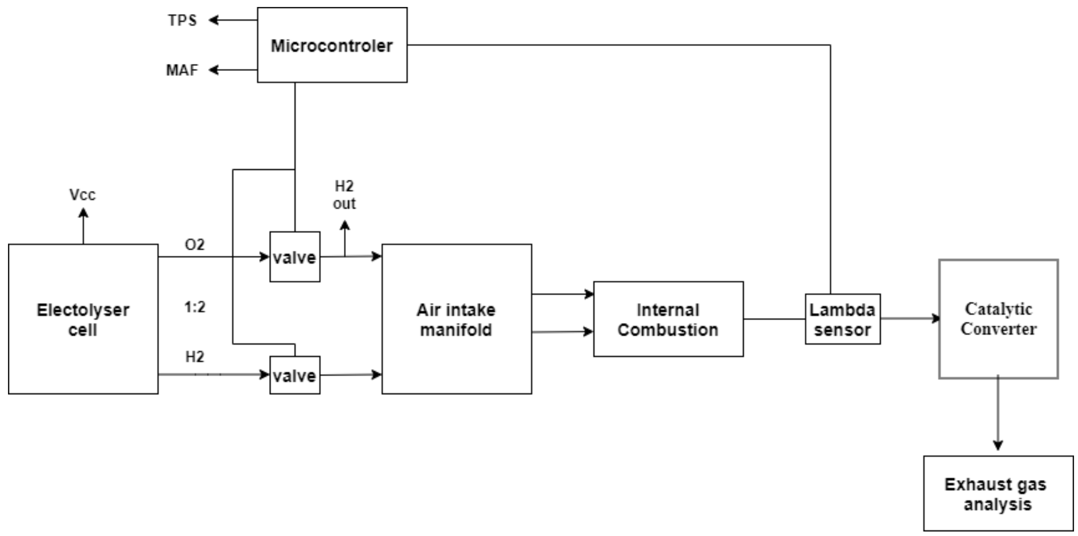

Figure 5.16: Final experimental design.

5.6 Microcontroller work algorithm

The work of the system is in a sequence of arithmetic operations and permanent monitoring of the readings of the system sensors to achieve the best possible efficiency and safety, as the microcontroller will do all these things so that any malfunction or sudden development in the work of the system will separate electrical power from the system in addition to entering the correct quantities of oxygen and hydrogen gas into the rooms combustion, where an electronic board was designed to be controlled by an Arduino programmer and the electronic components that were used:

1. Transistor: It is used as an electric switch to pass a high current.

2. Resistance: It was used as a pull-down to avoid the passage of low currents.

3. Relay: To control the passage of currents to the valves or the disconnection of the current.

The decision was made from the Arduino by receiving a signal from the throttle angle sensor and mass air flow sensor:

- Throttle position sensor: determines the angle at which the gate is opened to allow air to enter to determine the number of engine revolutions.

- Mass air flow : It measures the amount of air entering the engine and based on that determines the amount of fuel to be entered into the engine, where in the event of any malfunction affecting the sensor's work, the controller will stop the cell's work to avoid a malfunction in the engine's work

After connecting all the components, the control circuit became as in the figure 5.17

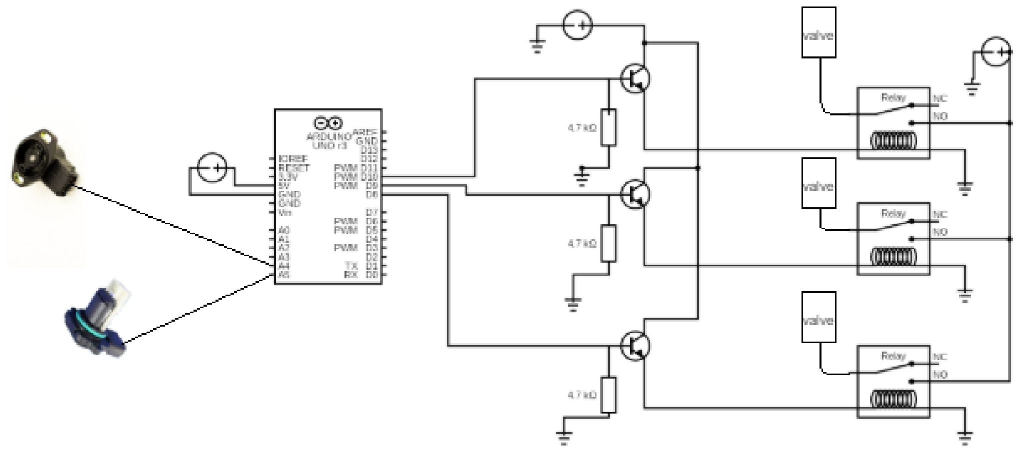

Figure 5.17: Oxygen and hydrogen gas control circuit diagram.

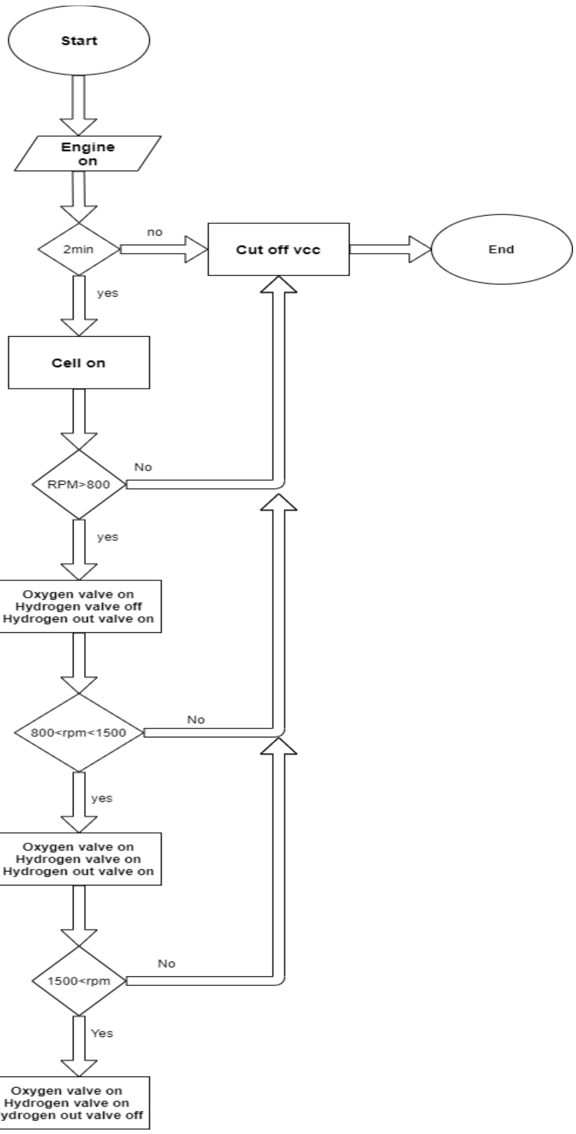

Figure 5.18: Flow chart of microcontroller.

Chapter Six

Results and discussion

6.1 Hydrogen gas and oxygen production

The hydrogen and oxygen gas that were separated from the water from the alkaline cell were measured using laboratory tubes to measure the volume of the resulting gas. The experiment was performed using a multi-ampere at 13.5 volts and was controlled by increasing the conductivity of the water which was measured by TDS and the results were as it is shown in Figure 6.1

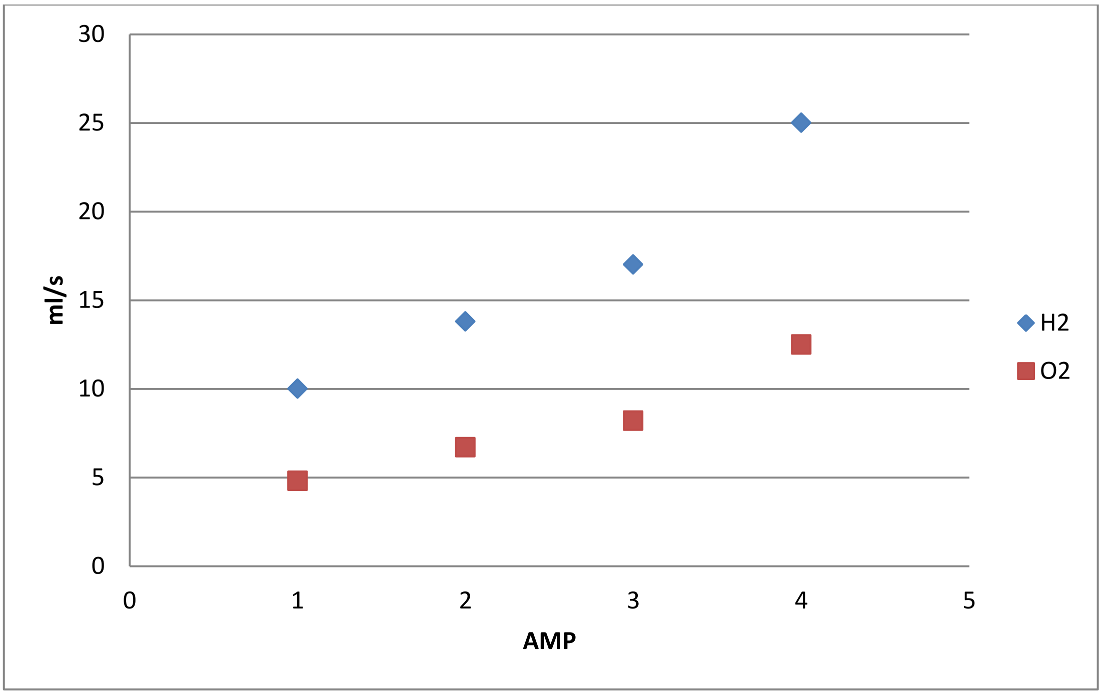

Figure 6.1: Comparison of the effect of current on the volume of oxygen and hydrogen produced.

6.2 Conductivity of water

Pure water has its conductivity close to zero due to the absence of impurities or salts. The amount we need for the cell is a liter of water, 165 grams of sodium hydroxide added to it, to increase its conductivity that was measured using the TDS device, so that the current drawn is 2 amperes to ensure the production of an appropriate amount from oxygen gas and hydrogen gas where the percentage of NaOH dissolved in water is 3.36 ppt as shown in figure 6.2.

Figure 6.2: Measurement of total dissolved solids.

6.3 Engine Torque

The engine torque was measured before modified the engine in order to record the system's efficiency. The engine torque readings would be taken using the VCDS program at ECTS 90C° and the readings were as in the table 6.1

Table 6.1: Normal engine torque without system running.

RPM	Engine torque (N.m)
800	24
1000	26
1250	30
1500	32
1750	33
2000	34
2250	35
2500	36
2750	38
3000	36
3250	36
3500	34

After the cell was installed, torque increased significantly at each rpm engine without damaging the engine the results are as shown in the table 6.2

Table 6.2: The effect of adding oxygen and hydrogen on engine torque.

RPM	Engine toque
800	40 N.m
1000	42 N.m
1250	44 N.m
1500	45 N.m
1750	47 N.m
2000	48 N.m
2250	50 N.m
2500	50 N.m
2750	47 N.m
3000	44 N.m
3250	43 N.m
3500	41 N.m

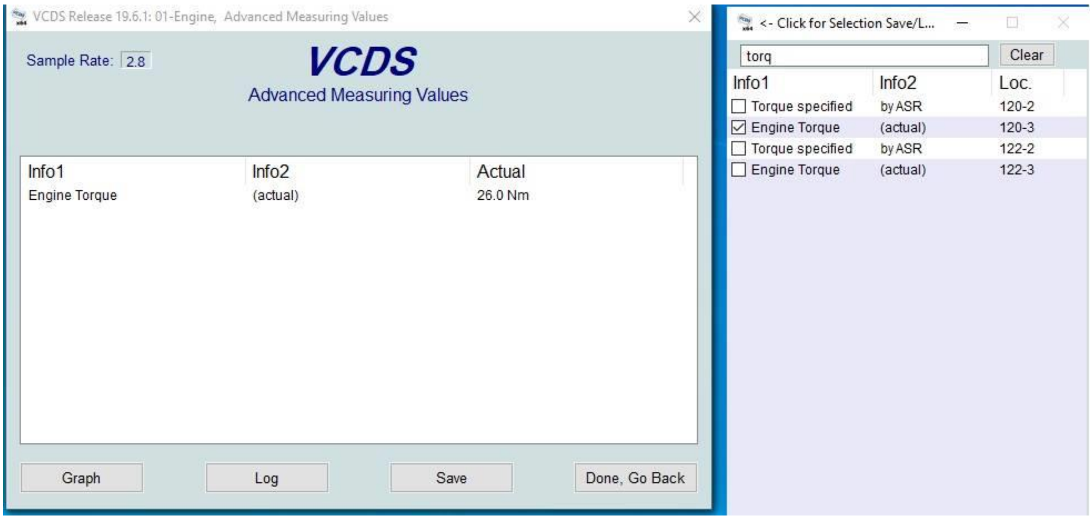

Figure 6.3: Engine torque without hydrogen and oxygen gas

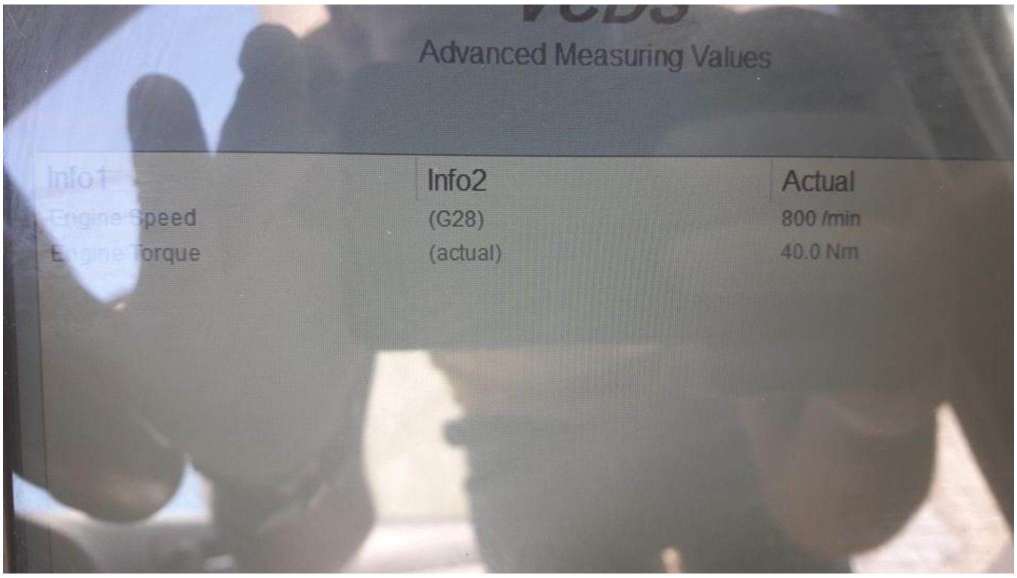

Figure 6.4: Engine torque after adding hydrogen gas and oxygen

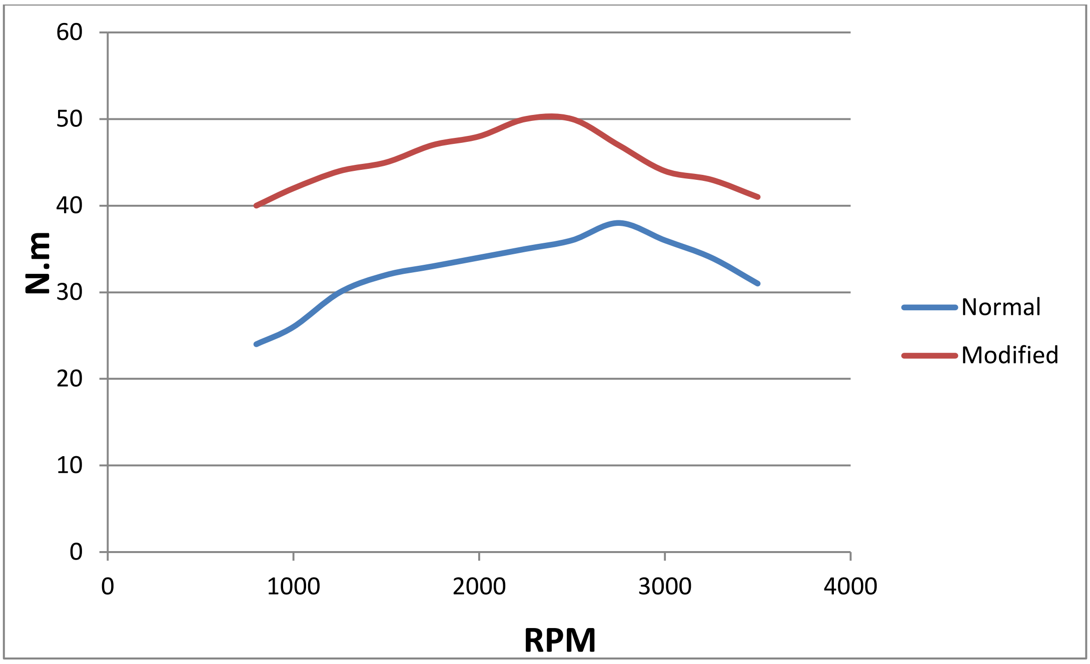

Figure 6.5: The effect of engine mod modification respect to rpm on torque.

As shown in Figure 5 that the modified engine torque reached its highest torque of 50 N.m at a speed of 2250, while in the normal engine reached its highest torque of 38N.m at a speed of 2750.

6.4 Analyze sensor readings

6.4.1 MAF Sensor

Mass air flow sensor readings were taken before the engine was modified to monitor system performance and efficiency. The readings were as shown in the table 6.3 at engine coolant temperature 90°C.

Table 6.3: Measure of air flow mass with rpm.

RPM	Air flow g/s
800	3.11
1000	3.25
1250	4.04
1500	5.02
1750	5.67
2000	6.70
2250	7.54
2500	8.29
2750	9.78
3000	10.16
3250	12.80
3500	13.29

6.4.2 Throttle position sensor (TPS)

Throttle sensor reading to determine the amount of fuel to be pumped based on the amount of air entering the engine as the voltage coming out of the sensor for ECM is the amount of angle the gate opened.

Table 6.4: Throttle position sensor reading

Rpm	Voltage	Throttle gate open
800	0.56v	6%
1000	0.82v	15%
1250	0.91v	18.5%
1500	1v	22%
1750	1.25v	25.5%
2000	1.45v	30%
2250	1.58v	32%
2500	1.84v	37.5%
2750	2v	41%
3000	2.16v	45%
3250	2.35v	48%
3500	2.5v	50.5%

6.4.3 Lambda Sensor

Reading the oxygen sensor to measure the efficiency of combustion between the air and the fuel, if it is stoichiometric or not**,** the readings are as in the table 5 at engine coolant temperature 90c$^{\circ}$

Table 6.5: Oxygen and temperature sensor readings.

RPM	Catalytic Convertertemp.	Oxygen sensor 1	A/F	Oxygen sensor 2
800	420c	0.82v	13:1	0.40v
1000	420c	0.86v	12.6:1	0.39v
1500	420c	0.86v	12.6:1	0.39v
2000	420c	0.86v	12.6:1	0.39v
2500	430c	0.760v	13.9:1	0.39v
3000	430c	0.70v	14:1	0.39v
3500	430c	0.70v	14:1	0.39v

After the engine worked with the cell running, the results showed that the A/F ratio is very close to stoichiometric condition , but the temperature of catalytic converter increased significantly, as shown in the table 6.6

Table 6.6: The effect of adding oxygen and hydrogen on fuel combustion efficiency and catalytic converter temperature based on table 7.

RPM	Catalytic converter temp.	Oxygen sensor 1	A/F	Oxygen sensor 2
800	510	0.50 v	14.5:1	0.41v
1000	510	0.50v	14.5:1	0.41v
1500	520	0.480v	14.6:1	0.41v
2000	530	0.480v	14.6:1	0.41v
2500	530	0.470v	14.7:1	0.41v
3000	530	0.470v	14.7:1	0.41v
3500	530	0.470v	14.7:1	0.41v

6.5 Engine fuel consumption

The average fuel consumption is measured by the amount of fuel that has been vented to the combustion chambers, with a unit of measurement (L/h) at the idle speed and a unit (L/100km) at the load speed.

The amount of oxygen and hydrogen entering the engine has been adjusted in variable rates based on the RPM of engine to ensure that the engine operates normally without disturbance as shown in table 6.7

Table 6.7: A/F ratio when the amount of oxygen and hydrogen entering the combustion chambers.

Rpm	Oxygen ml/s	Hydrogen ml/s	Lambda mV	A/F ratio
800	0	0	0.82	12.50
1000	0	0	0.86	12
1250	7.2	0	0.86	12
1500	7.2	0	0.48	14.5
1750	7.2	0	0.48	14.5
2000	7.2	7.4	0.48	14.5
2250	7.2	7.4	0.48	14.5
2500	7.2	7.4	0.52	14.2
2750	7.2	7.4	0.52	14.2
3000	7.2	14.8	0.51	14.15
3250	7.2	14.8	0.51	14.15
3500	7.2	14.8	0.51	14.15
3750	7.2	14.8	0.51	14.15
4000	7.2	14.8	0.51	14.15

At low engine speeds, oxygen and hydrogen will not be introduced into the engine, due to the failure of the backfire, which may lead to damage of the engine head, and then the oxygen entry alone begins from 1250 to 1750, and hydrogen has been ignored at these speeds because the speed of air intake and exhaust exit. It is not sufficient to keep up with the speed of hydrogen combustion. When the engine reaches the speed of 2000, hydrogen begins to enter the engine with half the amount produced, because the engine did not absorb the full amount without the occurrence of knocks that lead to disturbances in the engine and at a speed of 3000 gases were introduced with all the produced quantity because at high speeds the engine became absorbed The speed of hydrogen combustion without disturbances in it.

By using the ECM titanium program, the amount of fuel that was vented into the combustion chambers was reduced by a proportion to the reading of the oxygen sensor, so that no error appears in the combustion A/F ratio measures by the sensor, and the amount it reduced was 2% of the fuel sprayed by the injectors as shown in Table 6.7 and 6.8.

Table 6.8: The amount of fuel according to the throttle gate and rpm

RPM/throttle	8	17	25	33	42	50	58	67	75	83	92	100
700	102	22921	51017	31878	54722	32778	41075	53815	18997	48182	6745	28466
900	5785	40593	22987	65317	26194	47493	709	19578	53876	1208	48378	50779
1200	14404	32338	44592	47663	52313	38914	64087	26780	20666	23141	44591	62811
1400	55279	39857	30403	3620	60067	34115	36157	50133	64955	45850	7096	13172
1600	40802	47645	25683	33271	363	8420	7489	58088	40010	56879	11967	52803
1900	9403	21411	493	36514	7757	54613	21057	31802	7980	15989	44726	9344
2100	11127	48784	52484	42956	59811	1954	37437	53470	62256	3124	34401	18849
2300	59852	46500	32992	29489	52343	59719	48713	40156	49552	8084	4843	31968
2500	59413	5103	26691	15937	54913	41457	62080	4335	31872	32010	44923	37080
2800	30190	829	49778	48764	50612	29908	45857	61384	42964	37366	24985	30117
3000	20799	587	7930	45554	25624	24775	58369	663	14523	45943	27590	55619
3200	53060	48764	46525	63176	8197	41659	38042	42968	17237	26552	18928	36165
3500	63936	50288	34957	64761	9545	13222	49412	36072	55943	51146	48508	24236
3700	22456	28385	39945	55479	49877	16112	16893	32387	56028	7407	17753	35343
3900	6804	12032	21752	12261	56070	47547	10897	35399	48555	23530	52255	13597
4200	31541	25963	61556	65056	10266	58463	18264	4785	12742	10770	19681	7069
4400	45229	63262	52541	39159	49474	32353	667	15902	50850	52936	7781	58245
4600	14066	18037	64970	2394	9624	54248	35125	50729	32468	17012	27130	8584
4800	18260	47900	40841	63013	29877	13395	62941	64575	53992	33161	14712	20699
5100	21168	1956	58508	16579	62621	46279	46631	26316	8208	15406	48776	6849
5300	7693	50907	19449	27110	50497	55059	48778	16342	422	12152	22253	41589
5500	40560	20587	19660	41387	11683	452	64809	15114	44433	64228	37416	40412
5800	8397	57851	9777	11537	23337	15946	39186	45272	51823	61365	1370	35401
6000	2385	61842	21655	55590	30416	53121	35803	36393	63102	29129	50229	18585

Table 6.9: The amount of fuel modified according to the throttle gate and rpm based on table 6.7

RPM/throttle	8	17	25	33	42	50	58	67	75	83	92	100
700	102	22921	51017	31878	54722	32778	41075	53815	18997	48182	6745	28466
900	5785	40593	22987	65317	26194	47493	709	19578	53876	1208	48378	50779
1200	14404	32338	44592	47663	52313	38914	64087	26780	20666	23141	44591	62811
1400	55279	39857	30403	3620	60067	34115	36157	501	64901	45850	7096	13172
1600	40802	47645	25431	32975	360	8364	7447	57780	39825	56753	11954	52803
1900	9403	21411	488	36207	7700	54268	20946	31606	7955	15955	44679	9344
2100	11127	48784	52014	42614	59395	1942	37251	53212	62052	3118	34367	18849
2300	59852	46500	32714	29268	52000	59384	48485	39888	49385	8069	4838	31968
2500	59413	5103	26480	15825	54576	40110	61808	4310	31742	31954	44884	37090
2800	30190	829	49411	48445	50322	29761	45669	61111	42876	37305	24965	30117
3000	20799	587	7876	45277	25488	23550	58147	661	14460	45873	27569	55619
3200	53060	48764	46231	62821	8157	41484	37909	42785	17156	26515	18915	36165
3500	63936	50288	34755	64428	9502	13171	49253	35913	55812	51080	48477	24236
3700	22456	28385	39735	55219	49673	16055	16844	32291	55910	7398	17743	35343
3900	6804	12032	21649	12209	55863	46270	10868	35286	48440	23505	52227	13597
4200	31541	25963	61297	64813	10232	58299	18221	4762	12710	10760	19672	7069
4400	45229	63262	52347	39031	49332	32274	652	15812	50685	52896	7778	58245
4600	14066	18037	64765	2387	9600	53120	35001	50603	32410	17000	27120	8584
4800	18260	47900	40734	62866	29816	13372	62810	64412	53892	33142	14708	2069
5100	21168	1956	58385	16548	62518	46214	46495	26201	8202	15399	48765	6849
5300	7693	50907	19418	27072	50435	55001	48699	16278	422	12148	22249	41589
5500	40560	20587	19639	41348	11673	452	64701	15096	44417	64213	37412	40412
5800	8397	57851	9772	11532	23327	15940	39091	45195	51814	61358	1370	35401
6000	2385	61842	21655	55590	30416	53121	35782	36251	63102	29129	50229	18585

The previous tables show the change in the amount of fuel that has been reduced, as the quantity differs at each engine speed and throttle angle, and at certain speeds, no change occurs as it was controlled using a titanium program, where in Figure 6 different readings were taken before and after the adjustment to clarify the reduction in the amount of fuel.

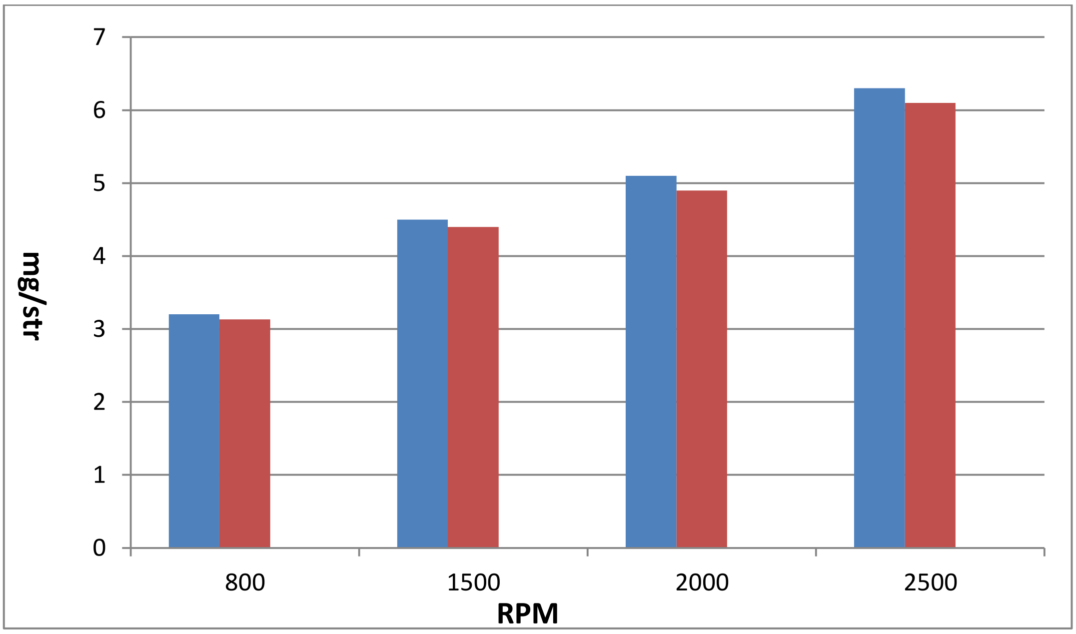

Figure 6.6: The amount of fuel reduced after modified the engine.

6.6 Exhaust gases

The gases that come out of the exhaust after installing the system, which were measured by several devices, such as their (vcds, AS8700A, air quality detector) the results appeared unevenly. Some gases had noticeable results, others were not affected, and some of them appeared negatively, as shown in the table 6.10 and 6.11.

Table 6.10: Exhaust emissions gases before modifying.

RPM	CO	CO_2	VOC	NO_x	H_2O
800	580ppm	2050ppm	5ppm	500ppm	Un clear
1000	600ppm	2210ppm	6ppm	520ppm	Un clear
1250	706ppm	2270ppm	6.315ppm	450ppm	Un clear
1500	768ppm	3240ppm	7.9ppm	450ppm	Un clear
1750	811ppm	3500ppm	8.25ppm	430ppm	Un clear
2000	932ppm	3980ppm	8.80ppm	435ppm	Un clear
2250	More than 1000ppm	4215ppm	9.19ppm	430ppm	Un clear
2500	More than 1000ppm	4700ppm	10.25ppm	425ppm	Un clear
2750	More than 1000ppm	5400ppm	11ppm	410ppm	Un clear
3000	More than 1000ppm	5760ppm	More than 12ppm	390ppm	Un clear

Table 6.11: Exhaust emissions gases after modifying

RPM	CO	CO_2	VOC	NO_x	H_2O
800	403ppm	2050ppm	5ppm	500ppm	A lot
1000	600ppm	2210ppm	6ppm	520ppm	A lot
1250	642ppm	2270ppm	5.10ppm	395ppm	A lot
1500	701ppm	2970ppm	5.98ppm	370ppm	A lot
1750	762ppm	3150ppm	6.80ppm	325ppm	A lot
2000	813ppm	3530ppm	7.60ppm	310ppm	A lot
2250	899ppm	3980ppm	8.20ppm	310ppm	A lot
2500	942ppm	4250ppm	8.90ppm	280ppm	A lot
2750	More than1000ppm	5010ppm	9.15ppm	280ppm	A lot
3000	More than 1000ppm	5350ppm	10.25ppm	270ppm	A lot

The figures show the effect of increasing the concentration of oxygen in the air and the introduction of hydrogen into the engine on the concentration of the emitted exhaust gases, as at the start of the engine operation. No change occurred because oxygen and hydrogen were not introduced into the engine, and then the concentration of gases began to decrease in different rates at each RPM.

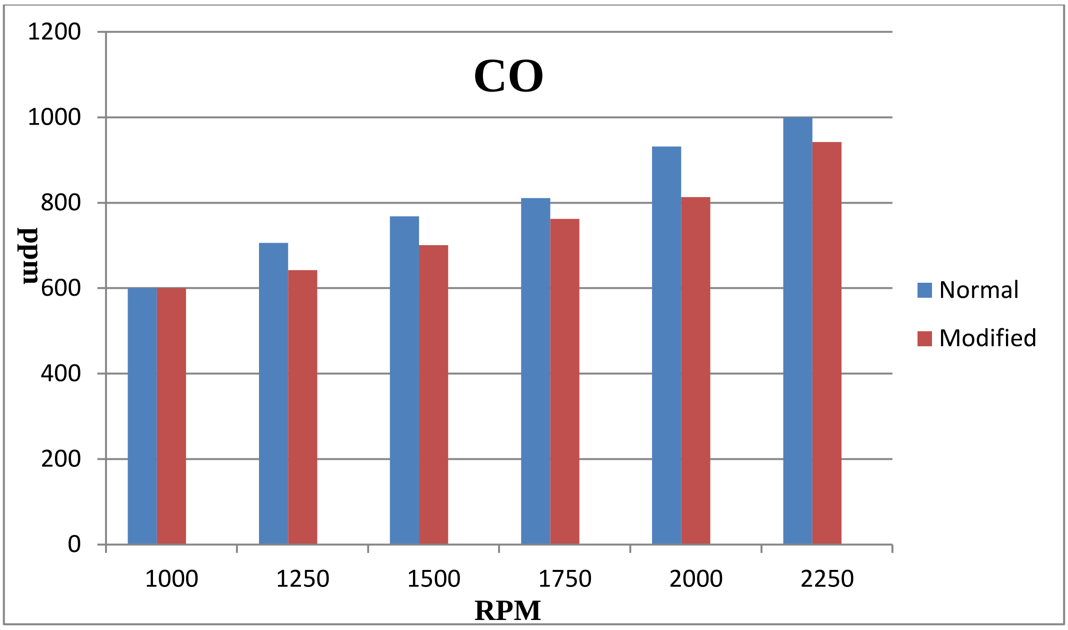

Figure 6.7: The effect of adding oxygen and hydrogen on CO gas.

Carbon monoxide did not change at low speeds due to the lack of hydrogen or oxygen entering the engine to ensure that there was no backfire, while after that the gas began to decrease in a certain amount as a result of the introduction of oxygen and hydrogen in addition to the increase in temperature in the combustion chambers and the rate of decrease in Carbon monoxide concentration 8.4%.

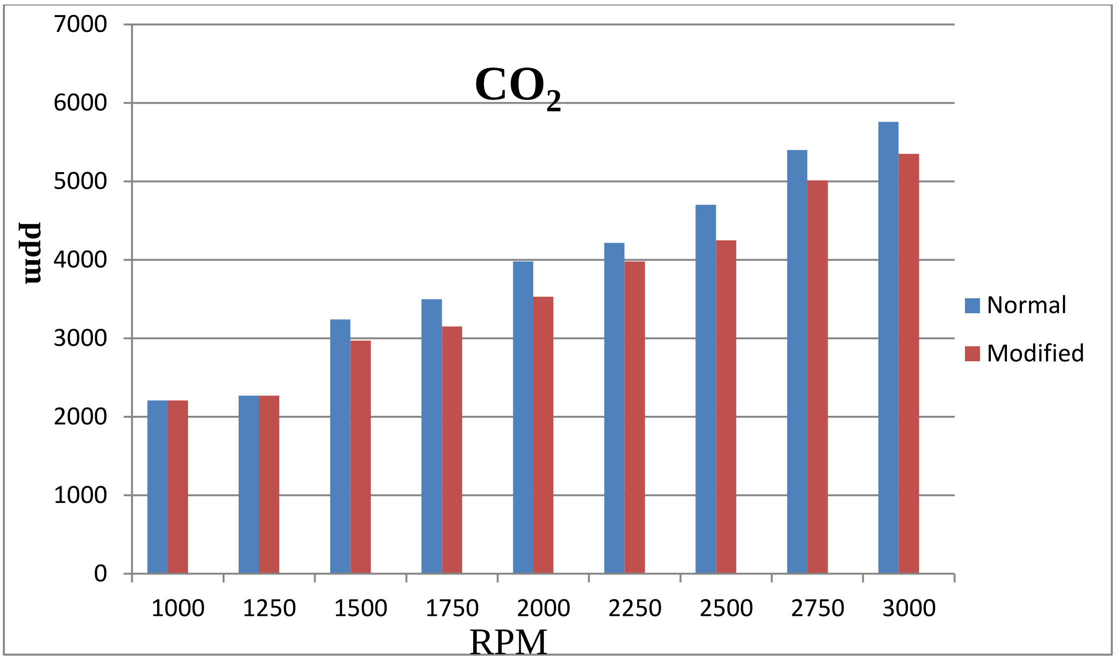

Figure 6.8: The effect of adding oxygen and hydrogen on CO2 gas.

The change in carbon dioxide was not significant because it was natural to produce as a result of fuel combustion, and it decreased by 5.4% as a result of reducing the amount of fuel pumped to the engine by 2%.

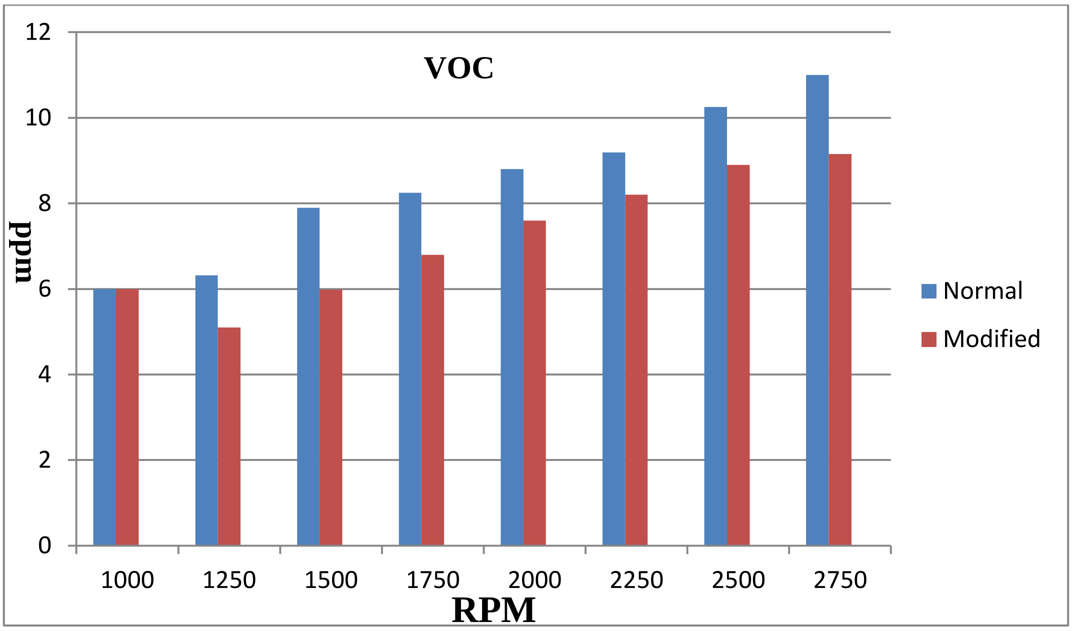

Figure 6.9: The effect of adding oxygen and hydrogen on VOC.

Volatile organic compounds decreased significantly by 13.2%, due to optimizing combustion after low speeds, in addition to reducing the amount of fuel.

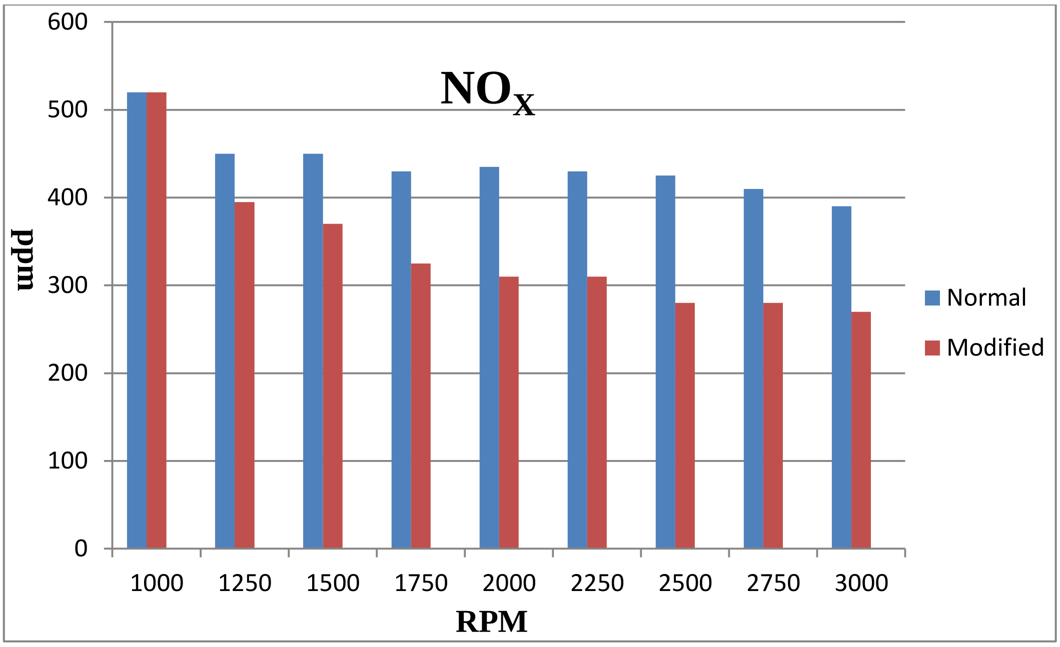

Figure 6.10: The effect of adding oxygen and hydrogen on NOX gas.

Nox gas at medium speeds decreased at a slight rate as a result of oxygen entering the combustion chambers and increasing its efficiency. But at high speeds the discrepancy became noticeable due to the entry of hydrogen and the decrease rate was 20%

Chapter Seven

Conclusion and Recommendation

7.1 Conclusion

The main objectives of this research were to design a cell that separates oxygen and hydrogen from water of the type of alkaline and installs them on the engine so that the system enters oxygen and hydrogen separately into the combustion chambers in quantities calculated based on reading the sensors responsible for the amount of air and fuel entering the engine such as (MAF)using a microcontroller and modifying the engine computer software Using a ECM Titanium program, to ensure that the engine works normally without disturbing its work, in addition to monitoring the exhaust gases before and after operating the system, and monitoring the engine's torque and consumption and the load on the alternator**.**

After installing the system on the car engine and introducing hydrogen and oxygen gas into the combustion based on the amount of air entering from the MAF sensor, the results showed that the concentration of exhaust gases was reduced as the carbon monoxide was reduced by an average 8.4%, CO_2 5.4%, VOC 13.2% and NO_x 20%.

As a result of the increase in the concentration of oxygen gas in the air and the introduction of a percentage of hydrogen gas into the combustion chambers, this led to a clear increase in the engine’s torque by 20% without occurrence of strikes in the work of engine or the occurrence of backfire.

But this increase led to an increase in the temperature of the engine and catalytic converter.

Economically, the fuel consumption was reduced by 8% than it was previously, as the test was carried out on the car in the idle state and the engine expense was reduced by 0.1 L/h. The experiment was repeated in the case of driving and it was for a distance of 10 km where fuel consumption was reduced by 0.1 litter, which equates to saving 525 NIS for a person who consumes 1200 liters per year.

The car alternator that feeds all the system in the car increased the load on it because of the system belonging to the cell that were installed in the car, as the load on the alternator was no more than 50%, but after five minutes of running the system, the load on it became 72%, which is normal and does not pose any danger to alternator or car systems.

All that happened can be summarized as follows:

- Environmentally, emissions of CO_2, CO, VOC and NO_x gases have been reduced.
- Water vapor has increased its exit from the exhaust because oxygen and hydrogen gases are saturated with water vapor.
- Engine torque increased by 20%.
- The temperature of the engine and the catalytic converter increased due to the increased concentration of oxygen in the air.

- Overloading the car alternator due to system operation did not affect its operation.
- The aluminum sheets that were used in the cell could not handle the reaction that takes place as a result of the electric current passing through it.
- The system cannot be used at low speeds or when the engine is cold to ensure that backfire does not occur and because the quantities of fuel entering the engine are different.
- The engine software has been modified to reduce the amount of fuel entering the engine to ensure that no vibration occurs in the combustion chambers using the ECM Titanium program.
- Hydrogen gas is not stored as the excess is disposed of or at times when we do not need it by solenoid valve that exits the gas to the atmosphere.

7.2 Recommendations

In this section, after targeting the previously defined goals, there are several suggestions and ideas that will help in developing the system or as useful future research because of the need for more time and insufficient money to purchase all the requirements for the very expensive measurement that can lead to more accurate and clear results on the subject in addition to the difficulty Obtaining them from the local closed market, which makes finding devices very difficult. Some recommendations that will help future researchers on the same research:

- The use of titanium plates in the hydrogen and oxygen separation cell from water, because titanium is more effective than other metals in electrolysis in addition to the depletion of less current and its life span is much higher than most minerals as it does not disintegrate over time and needs less cleaning and maintenance.

- Use a separate battery from the car to ensure that no overload occurs on the car battery and the alternator, because this may affect some sensitive parts such as the DSG automatic transmission.

- The addition of an electric water pump (aux heat) to accelerate the engine cooling process to get rid of the excess heat caused by the increase in the concentration of oxygen in the air and to maintain the performance of the catalytic converter, where the pump is placed at the outlet of the water reaching the radiator.

- Using devices to purify gases and to dehydrate it from water vapor to obtain the best combustion in addition to preserving the catalytic converter.

- Introduce the hydrogen that has been expelled out into the catalytic converter in order to avoid burning it outside the car or in the event of a collision

References

- S. A. Musmar og A. A. Al-rousan, "**Effect of HHO gas on combustion emissions in gasoline engines"**, bd. 90, s. 3066–3070, 2011.
- https://en.wikipedia.org/wiki/Stoichiometry
- B. Subramanian og S. Ismail, ***"ScienceDirect Production and use of HHO gas in IC engines",*** **Int. J. Hydrogen Energy,** 2018.
- www.researchgate.net
- A. Rimkus, "A**ccepted Manuscript**", bd. 2, 2018.
- Mustafi Nirendra, N., Ruhul, A. M., Zakaria, A. M., & Mayeedul, I. M. (2013). An Investigatio n on the production
- P. Dimitriou, T. Tsujimura, og Y. Suzuki, "**Hydrogen-diesel dual-fuel engine optimization for CHP systems"**, *Energy*, 2018.
- A. A. Al-rousan, "***Reduction of fuel consumption in gasoline engines by introducing HHO gas into intake manifold***", **Int. J. Hydrogen Energy,** bd. 35, nr. 23, s. 12930–12935, 2010.
- M. M. El-kassaby, Y. A. Eldrainy, M. E. Khidr, og K. I. Khidr, "***Effect of hydroxy (HHO) gas addition on gasoline engine performance and emissions"***, **Alexandria Eng. J.,** bd. 55, nr. 1, s. 243–251, 2016.

- P. Polverino, F. D. Aniello, I. Arsie, og C. Pianese, **“Study of the energetic needs for the on-board production of Oxy-Hydrogen as fuel additive in internal combustion engines”,** Energy Convers. Manag., bd. 179, nr. September 2018, s. 114–131, 2019.

- E. Orak, **“EFFECT OF HYDROGEN ADDITION ON EXHAUST EMISSIONS AND PERFORMANCE OF A SPARK IGNITION ENGINE”,** bd. 14, nr. 3, s. 665–672, 2015.

- C. Park, Y. Kim, Y. Choi, og J. Lee, ***“ScienceDirect The effect of engine speed and cylinder-to-cylinder variations on backfire in a hydrogen-fueled internal combustion engine***”, **Int. J. Hydrogen Energy,** bd. 44, nr. 39, s. 22223–22230, 2019.

- P. Dimitriou, T. Tsujimura, og Y. Suzuki, “***ScienceDirect operation e A combustion efficiency improvement approach”***, **Int. J. Hydrogen Energy,** bd. 44, nr. 31, s. 17048–17060, 2019.

- X. Yu *m.fl.*, “***ScienceDirect Numerical study on effects of hydrogen direct injection on hydrogen mixture distribution , combustion and emissions of a gasoline / hydrogen SI engine under lean burn condition”***, **Int. J. Hydrogen Energy,** nr. xxxx, 2019.

- P. B. Bijinraj og A. R. A, “S**cienceDirect A review on analysis of HHO gas in IC engines”**, Mater. Today Proc., bd. 11, s. 1117–1129, 2019.

- https://haynes.com/en-us/tips-tutorials/beginners-guide-what-four-stroke-engine
- https://www.chemistryviews.org/details/ezine/10636711/Emissions_of_a_Car.html
- C. Ji, S. Wang, og B. Zhang, "***Combustion and emissions characteristics of a hybrid hydrogen-gasoline engine under various loads and lean conditions”***, **Int. J. Hydrogen Energy**, bd. 35, nr. 11, s. 5714–5722, 2010.
- H. Yamada *m.fl.*, "**Detailed analysis of diesel vehicle exhaust emissions: Nitrogen oxides, hydrocarbons and particulate size distributions”**, Proc. Combust. Inst., bd. 33, nr. 2, s. 2895–2902, 2011.
- A. Tiwary og J. Colls, "**Science of the Total Environment Mitigating secondary aerosol generation potentials from biofuel use in the energy sector”,** Sci. Total Environ., bd. 408, nr. 3, s. 607–616, 2010.
- E. Rajasekar, A. Murugesan, R. Subramanian, og N. Nedunchezhian, "**Review of NO x reduction technologies in CI engines fuelled with oxygenated biomass fuels”**, Renew. Sustain. Energy Rev., bd. 14, nr. 7, s. 2113–2121, 2010.
- .http://premierautotrade.com.au/news/understanding-EGR-systems-pt-1.php

- R. Manojkumar, S. Haranethra, M. Muralidharan, og A. Ramaprabhu, "**Materials Today : Proceedings I . C . Engine emission reduction using catalytic converter by replacing the noble catalyst and using copper oxide as the catalyst**", Mater. Today Proc., nr. xxxx, 2020.

- https://www.researchgate.net/figure/Schematic-image-of-a-three-way-automotive-catalytic-converter-HC-Hydrocarbons_fig1_337203725

- M. M. Maricq, "**Chemical characterization of particulate emissions from diesel engines : A review**", bd. 38, s. 1079–1118, 2007.

- https://www.autoconverterrecyclers.com/selective-catalytic-reduction

- https://parts.olathetoyota.com/p0441-code-toyota

- https://electratherm.com/wpcontent/uploads/2015/04/Compressor_ Article_ 2015

- https://www.apogeeweb.net/electron/what-is-a-mass-air-flow-sensor.html

- https://www.thedrive.com/maintenance-repair/39618/throttle-position-sensor-symptoms

- https://www.car-bock.de/Lambda-probe-26206AAM

- M. Luj, "**Experimental assessment of pre-turbo aftertreatment con fi gurations in a single stage turbocharged diesel engine** . Part 1 : Steady-state operation", 2014.

- https://www.carsguide.com.au/car-advice/what-is-a-turbocharger
- https://carbiketech.com/compression-ratio/
- K. Zeng og D. Zhang, "**Recent progress in alkaline water electrolysis for hydrogen production and applications"**, Prog. Energy Combust. Sci., bd. 36, nr. 3, s. 307–326, 2010.
- https://www.researchgate.net/figure/Basic-scheme-of-a-water-electrolysis-system
- https://en.wikipedia.org/wiki/Solid_oxide_electrolyzer_cell
- M. Steilen og L. Jo, "**Hydrogen Conversion into Electricity and Thermal Energy by Fuel Cells : Use of H 2 -Systems and Batteries"**, s. 143–158, 2015.
- https://www.energy.gov/sites/prod/files/2016/11/f34/fcto_webinarslides_h2awsm_consortia_electrolysis_overview
- https://www.ross-tech.com/
- Z. Abdin, C. J. Webb, og E. M. A. Gray, "**Modelling and simulation of an alkaline electrolyser cell"**, Energy, bd. 138, s. 316–331, 2017.
- W. Shi, X. Yu, H. Zhang, og H. Li, "***Effect of spark timing on combustion and emissions of a hydrogen direct injection stratified gasoline engine",*** **Int. J. Hydrogen Energy,** bd. 42, nr. 8, s. 5619–5626, 2017.

- https://afdc.energy.gov/vehicles/how-do-gasoline-cars-work
- https://www.weh.com/weh-coalescing-filter-tsf2-h-for-installation-in-h2-vehicles-and-fueling-stations-product-family.html
- A. C. Yilmaz, E. Uludamar, og K. Aydin, "***Effect of hydroxy (HHO) gas addition on performance and exhaust emissions in compression ignition engines***", **Int. J. Hydrogen Energy,** bd. 35, nr. 20, s. 11366–11372, 2010.
- https://webstore.hfree.eu/en/accessories/34-tds-conductivity-meter.html
- https://lab-training.com/2017/07/20/measurement-gas-volumes-laboratories/
- https://www.amazon.co.uk/AS8700A-Monoxide-Analyzer-Detector-Handheld/dp/B083Y37JTJ
- .https://www.inox-rvs.com/en/disinfection-column-copy-115953250.html

جامعة النجاح الوطنية

كلية الدراسات العليا

تحسين كفاءة محركات الوقود عن طريق تحسين نسبة حقن H_2/O_2

إعداد

شفيق رائد شفيق ابو صاع

إشراف

د. عبد الرحيم ابو صفا

قدمت هذه الاطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في برنامج هندسة الطاقة النظيفة وترشيد الاستهلاك، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

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إشراف

د. عبد الرحيم ابو صفا

الملخص

في هذا البحث سيتم التركيز على زيادة كفاءة المحرك وكذلك تقليل نسبة غازات العادم عن طريق تشبع الاكسجين في الهواء الداخل للمحرك بعد تحليل قراءة حساس تدفق الهواء (maf) للحفاظ على نسبة الهواء الى الوقود الصحيحة حيث تم تعديل برمجة ECM المحرك لضمان عدم حدوث اضرابات في عمل المحرك او تشويش في قراءات الحساسات المسؤوله عن مراقبة كفاءة احتراق الوقود مثل Lambda sensor لزيادة قوة الاحتراق وبالتالي زيادة القدرة الحصانية بالاضافة فان تركيز غازات العادم (CO, CO_2, VOC ,NO_X) سيكون اقل مما كان عليه بسبب زيادة تركيز الاكسجين في الهواء وادخال الهيدروجين الى المحرك، يتم الحصول على الغازان من خلال خليه تفصل الاكسجين والهيدروجين من الماء باستخدام الفصل الكهربائي حيث يتم تغذية الخلية بفولتية السيارة 13.5 فولت واضافة محلول هيدروكسيد الصوديم لتحفيز الماء للفصل حيث يمر الغازان بشكل منفصل من خلال صمامات احاديه الاتجاه التي يتم التحكم بهما بواسطة متحكم دقيق لادخال الكمية المناسبة من الهيدروجين والاكسجين حسب عدد دورات المحرك. ستتم مراقبة النتائج باستخدام عدة اجهزة مثل (VCDS, DELPHI) التي تم استخدامها لقياس فولتيه الحساسات وقياس عزم المحرك وتركيز غاز NO_X بالاضافة الى استخدام اجهزة لقياس تركيز غازات العادم (AS8700A, Air quality detector) كما تم استخدام برنامج ECM Titanium لتقليل كمية الوقود الداخل للمحرك لضمان عدم حدوث اضطرابات في عمل المحرك .عند اضافة الاكسجين والهيدروجين الى غرف الاحتراق CO قل بنسبة 8.4% ,CO2 بنسبة 5.4%, VOCبنسبة 13.2% وغاز NOX بنسبة 20%.

للحصول على كفاءة اعلى للخلية يفضل استخدام الصفائح المصنوعة من التيتانيوم وذلك لان فاعليته اعلى من باقي المعادن والعمر الافتراضي له طويل كما انه موصليته للتيار الكهربائي عالية، وللتخلص من الحرارة العالية يجب اضافة مضخة ماء مساعدة (Aux Heat) وللتخلص من بخار الماء في العادم يجب استخدام مجفف لتصفية الماء الموجود في غاز الاكسجين والهيدروجين بعد الفصل.