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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE IMPACT OF HHO ENRICHMENT IN SINGLE-CYLINDER DIESEL ENGINE VIA SIMULATION ENVIRONMENT

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MASTER OF MECHANICAL ENGINEERING

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A thesis submitted

in the fulfillment of the requirements for the Master of Mechanical Engineering

Faculty of Mechanical Engineering

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2021

DECLARATION

I declare that this thesis entitled "The Impact of HHO Enrichment in Single Cylinder Diesel Engine via Simulation Environment" results from my research except as cited in the references. The idea has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : ....

Name : MUHAMMAD HAMIZAN BIN ROSNAZRI

Date : 25 AUGUST 2021

APPROVAL

As a result of this declaration, I have read this thesis. In my opinion, this thesis is sufficient in terms of scope and qualifies for the award of Master in Mechanical Engineering.

Signature : ....

Supervisor Name : PROF. TS. DR. NOREFFENDY BIN TAMALDIN

Date : 28 September 2021

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ABSTRACT

The technology is meant to serve people and their environment without harming them. For many years, fossil fuels like petroleum products and others have provided us with numerous benefits in many sectors. However, the issues with environmental pollution they create have been becoming worse, threatening both human and wildlife existence. This research study explores the emission and performance characteristics of a single-cylinder, four-stroke, direct injection diesel engine running on various kinds of diesel fuel Soybean Methyl Ester (SME) mixes using the Diesel-RK modeling program. It was discovered via calculated findings that the decrease in Bosch smoke number while using B5, B20, B40 and fuel compared to the addition of HHO gas. In addition, a decrease in Particulate Matter (PM) emissions is shown for the B5, a reduction for the B20 fuel, and also reduction for the B40. On average, each blend's thermal efficiency, power, and specific fuel consumption decreases in addition with HHO gas. NO_x emissions are much greater in blended, which generate higher NO_x levels than pure diesel fuel. An examination of how different variables influence retarding injection time was conducted. Found that holding out on injection time led to massive reductions in NO_x emissions. All of the tests were carried out under full load conditions and at engine speeds ranging from 1000 to 3000 rpm, respectively. The findings of the braking power, brake specific fuel consumption, and thermal efficiency tests were addressed from the standpoint of performance. In addition, carbon monoxide and nitrogen oxides are detected and displayed as exhaust emissions, respectively. The inclusion of HHO gas in biodiesel blends of B40 results in the lowest Bosch smoke number emissions and the lowest particulate matter emissions, but the highest NO_x emissions when compared to other biodiesel blends While B5 biodiesel blends produce the highest levels of emissions in terms of Bosch smoke number and particulate matter, they do not produce the highest levels of NO_x emissions. The specific fuel consumption of biodiesel blends of B5 is the greatest when compared to other blends, while the specific fuel consumption of B40 + HHO gas is the lowest among other blends.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MIE	-	Minimum Ignition Energy
B5	-	Blend containing 95% of diesel fuel and 5% blends by volume
B20	-	Blend containing 80% of diesel fuel and 20% blends by volume
B40	-	Blend containing 60% of diesel fuel and 40% blends by volume
BMEP	-	Brake Mean Effective Pressure
BSFC	-	Brake Specific Fuel Consumption
BSN	-	Bosch Smoke Number
BTDC	-	Before Top Dead Centre
CO	-	Carbon Monoxide
NO_x	-	Nitrogen Oxide
PM	-	Particulate Matter
RPM	-	Revolution per Minute
SME	-	Soybean Methyl Ester
TDC	-	Top Dead Centre
SFC	-	Specific Fuel Consumption
PEM	-	Polymer Electrolyte Membrane
W/Lpm	-	Watt/Litre per Minute
HHO	-	Oxyhydrogen / Hydroxide
KOH	-	Potassium Hydroxide
HC	-	Hydrocarbon
KOH	-	Potassium Hydroxide
WCO	-	Waste Cooking Oil

CHAPTER 1

INTRODUCTION

1.1 Overview

The use of fossil fuels is expanding internationally to meet current world energy requirements. The reserves of fossil fuels are exponentially declining (Barreto, 2018). The present consumption trend is predicted to endure 34 years; coal, about 107; and natural gas, about 37 years (Shafee and Topal, 2009). Fossil fuels and their effects on pollution have recently motivated researchers to create clean fuels. Hydrogen is the only renewable fuel without containing carbon. Limiting fuel carbon lessens the emission of the engine (except NO_x) (Najafi et al., 2021). Hydrogen is an accessible and unending supply of fuels as a clean and ecologically favorable fuel (Arat, 2019). Energy is derived by burning from fossil sources. Many of this Energy is wasted owing to inefficiencies in the conversion mechanism during conversion to usable jobs.

The motors for compression ignition (CI), powered by heavy machinery of the world, are also widely used for motors vehicle and marine transport because of their high torque and efficiency in motors and their ability to operate on mixtures of lean air fuel compared to spark ignition (SI) motors that mainly use diesel or heavy fuel. The efficiency of CI Engines ranges from 20% to 35%, with a maximum performance of just approximately 54.4% achieved with diesel (Takaishi et al., 2008).

The fundamental difficulty with CI engines is the inadequate mixture of air and fuel since fuel is injected at the end of the pump. Combustion also happens spontaneously in the air-fuel combination at every site. Spontaneous combustion takes occurs at various periods throughout the power stroke. These locations serve as a focus of flame spread. A high fuel speed fuel would cause the diesel fuel to burn soon after the initial spontaneous combustion, resulting in high torque and power.

Hydrogen is a high-fuel fuel with an inflammation range of 4-75% by air volume, which is quite high, compared to 0.7%–5% by volume, for diesel fuel. It also has a high diffusion coefficient of 0.61 $cm^2\ s^{-1}$, enabling the combustion chamber to create a homogenous combination of air and fuel (EL-Kassaby et al., 2016). Hydrogen also has a high laminar flame speed, the speed with which flame spreads and hence quick-burning happens. Air hydrogen mixes have a Minimum Ignition Energy (MIE) of 0.065 MJ, much below the air mixture MIE, 0.2–0.3 MJ (Von and Kunz, 1998). While low MIE is desired for combustion, the air-fuel mixture may be ignited before the compressive stroke is completed. Hydrogen alone cannot be utilized in CI engines since the hydrogen's high auto-ignition temperature of 858 K would demand a very high compressive rate (Aydin and Kenanoglu, 2018). It may be used in a CI engine as a fuel that supports diesel. It has demonstrated encouraging results, improved efficiency, and increased CI engine torque performance (Köse and Ciniviz, 2013). However, hydrogen induction with diesel influences the diesel engine air/fuel ratio, restricting the quantity of hydrogen supplied for desirable results. This is because hydrogen utilizes part of the oxygen available in the air, leading to inefficient combustion of fuel and lower efficiency (Juknelevičius et al., 2019).

Oxyhydrogen (HHO) was created as a solution to the low oxygen issue. HHO is a hydrogen and oxygen mixture. If H_2 and O_2 are in the 2:1 volume ratio, the combination is termed Brown's Gas. If HHO is fed into the CI engine, the stoichiometric oxygen requirements for hydrogen combustion are combined with the whole hydrogen. This means that even at high HHO flow rates, diesel will have a suitable supply of oxygen. HHO may be predicted to significantly enhance the combustion characteristics of the engine and enhance engine performance in turn. This study analyses the usage of HHO in the CI engine in conjunction with diesel using a sweeping 315cc engine, much less than any prior investigation. Such a little engine might be utilized in tiny autos and motorcycles that contribute to a major part of the world's fossil fuels if made more efficient using HHO.

Electrochemical, biological, and thermochemical processes may be used to create hydrogen. Figure 1.1 shows multiple techniques of hydrogen synthesis. The best hydrogen production technique is water electrolysis (Baltacioglu et al., 2019) with renewable energy sources such as solar and wind resources (Najafi et al., 2021b).

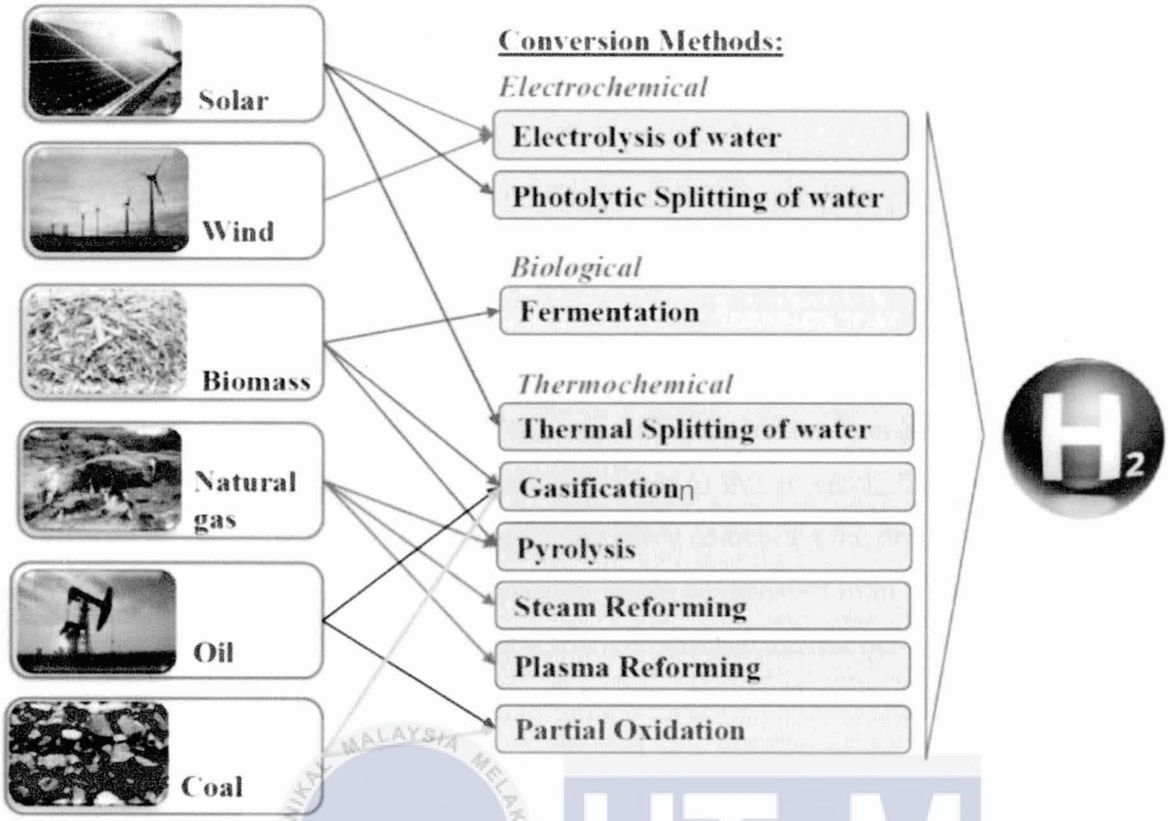

Figure 1.1 The numerous techniques of hydrogen generation (Najafi et al., 2021b).

Hydroxy gas has one mol hydrogen and two oxygen moles (Premkartikkumar et al., 2014). A diesel engine that utilizes gas-powered fuel like gas, biogas and hydrogen is a dual-fuel diesel engine (Akbarian et al., 2018). Studies show that HHO gas is combustible greater than diesel fuel (Premkartikkumar et al., 2014). Therefore, the combustion process in diesel engines may be improved. Hydrogen use raises the fuel H/C ratio and minimizes carbon-based emissions (Szwaja and Grab-Rogalinski, 2009). Furthermore, the diffusion rate of hydrogen gas in air is quite high, minimizing diesel fuel injection inhomogeneity and generating a homogeneous fuel-air mix (Ismail et al., 2019).

The publications reviewed demonstrate that using HHO gas in diesel engines enhances motor performance and decreases pollutants. HHO gas is a novel and sustainable source of Energy that may offer current and future energy security. According to the authors' best knowledge, the effects of low HHO as addition and HHO and biodiesel interaction have not yet been described. A HHO gas generator was devised and produced in this research. The impacts on a dual fuel diesel engine using HHO gas and diesel-biodiesel blends were then examined.

1.2 Problem Statement

Electrochemical, biological, and thermochemical processes may be used to create hydrogen. Figure 1.1 shows multiple techniques of hydrogen synthesis. The best hydrogen production technique is water electrolysis (Baltacioglu et al., 2019) with renewable energy sources such as solar and wind resources (Najafi et al., 2021b).

The major objective of the research is to compare the emissions from earlier innovations on the biodiesel fuel with HHO enrichment that leads to this research. The prior experiment provides emission data using an actual engine while comparing the preliminary experiment data using simulation software. The program might be different from the outcome depends on the input before the simulation is executed. The software has numerous limits, which take a long time to create the engine specifications since they need constant interaction between the developer Oxyhydrogen (HHO) was created as a solution to the low oxygen issue in biodiesel internal compression engine. The studies of HHO gas with biodiesel blends have not been widely done specifically in industries application field. The studies of using different fuels concentration and the appearance of HHO gas with different engine speed and how the engine performance and emissions of the systems have not widely done. However, the environmental difference where the project is conducted using systems (software) may not be precise. The simulation will test with the B5, B20, and B40 biodiesel fuels effect on engine performance and emissions with and without the HHO input.

1.3 Research Objectives

The purpose of the research are:

a) To investigate the Biodiesel B5, B20, and B40 biodiesel engine performance and emission as the baseline for diesel engine emissions via simulation environment.
b) To commission HHO cell generator as H_2 enrichment to diesel engine using simulation software.
c) To perform analysis impact of B5, B20, and B40 with H_2 enrichment.

1.4 Scope and Limitations

Many variables should be linked to achieving the objectives. However, this analysis is confined to three factors: the HHO module, diesel exhaust emissions, and biodiesel fuel. These variables are derived from the literature review of the thesis and are seen as factors the use of diesel engine.

This study is restricted to the constructional type by considering the project design since no diesel engine and HHO module are given but only simulation software due to lab restrictions because of lockdown on pandemic COVID-19. The data obtained are may does not include other diesel engines or other simulations. The findings could be different if tested on various engine types.

The hydroxy (HHO) or Brown's gas generated from the water analysis uses different biodiesel fuel settings in this work. It uses different types of biodiesel fuel, being run with the diesel engine simulation with and without the HHO Generator module as the variable. HHO gas will be generated by the volume of water. The emissions generated from the software being recorded and observed.

The software has many constraints which require a long time to build the engine specs since the developer and engineer require regular contact. This existing system of mobility restriction, which limits university access, which give some difficulties to gain data. The outcomes of the previous study are compared with the best outcomes from the simulation run. However, somehow the environmental difference may not be accurate if the project is carried out using systems (hardware and software).

1.5 Structure of Thesis

This work consists of five chapters. The first chapter addresses the context of the study, the value of the thesis, issue statement, key thesis goals, research methods, and limitations. Chapter Two (literature review) gives an extensive overview of topics such as the significance of the HHO module generator, study history evidence from articles, newspapers, blogs, the HHO generator factors, biodiesel fuelling forms, and the influence of biodiesel on pollution and environmental impacts on engine exhaust emissions. The third chapter (methodology) presents techniques for collecting and analyzing the data gathered for results. The fourth chapter (results and discussion) examines the effects and attempts to explain how to answer the report's key concerns. The end chapter (recommendations, conclusion, and possible work) concludes all findings of this study, contrasts the cases chosen and redefines design-dependent techniques to be followed by designers, and sets out a checklist. The structure of this study is seen in Figure 1.2.

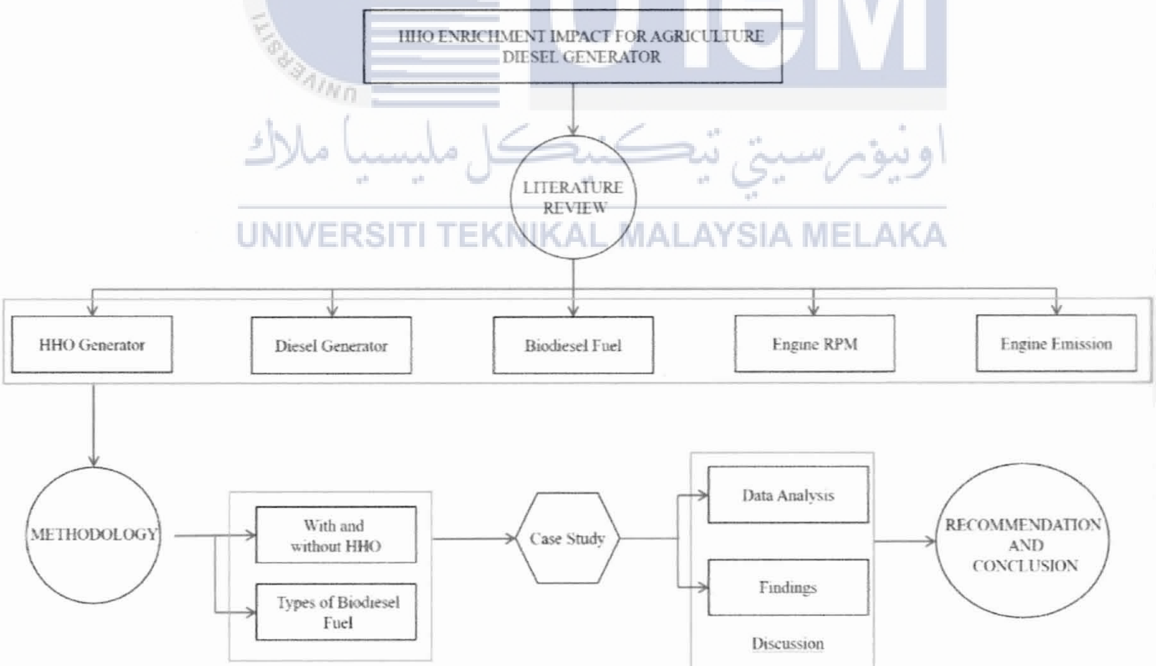

Figure 1.2 The structure of study for this research project

CHAPTER 2

LITERATURE REVIEW

2.1 Chapter Introduction

This section of the literature evaluation assesses the writing, papers, journals, and research data of a research project studying the effects of hydroxy gas on the emittances of diesel engine generators with biofuel factors.

Natural gas must be researched to discover the answer to this energy challenge. Natural gas is believed to be the alternative, and so are the coals. However, natural gas and coals are also considered fossil and non-renewable energy sources, so these alternatives are not enough to meet energy demands in the future. Many attempts have been undertaken to replace hydrocarbon energy with the new renewable energy alternative. Alternative energy includes solar energy, water's energy potential and biomass energy (Nurachamad, 2013; Sutomo et al., 2011).

2.2 HHO Gas

Hydrogen (H_2) energy is one of those most investigated options since hydrogen is, although it comes in a compound, the most important element in the world. Hydrogen may be easily used to replace hydrocarbon fuel without modifying the present machine structure to cause excessive heat, and the emissions are near low (Nurachamad, 2013; Sutomo et al., 2011). Hydrogen has increased flame speed and can be fired more quickly with its gasoline mixture. Nonetheless, when H_2 addition extends the mixture flammability limit to thinner fuel equivalency, the reaction rate will be decreased, and combustion under lean circumstances will extend (Ji et al., 2010).

An electrolyzer is required to turn water into hydrogen fuel. The electrolyzer is a hydrogen and oxygen-hydrogen separating machine or equipment for brown gas production. This machine has also been termed a generator of hydrogen. Electrolysis is the process of allowing the electrical flow to separate the molecule into its original components, whereas water electrolysis means separating the water molecule back from its original components by allowing the electrical flow to flow into it. This electrolyze produces Hydroxide (HHO) gas (Irfana Diah Faryuni et al., 2013)

In their research paper, Patil et al., 2017 stated that HHO gas was produced as an electrolyte by the KOH water electrolysis method. Four-stroke, single-cylinder gasoline engine was employed as a supplementary fuel for performance testing with HHO gas supplied through the air intake. The performance was achieved using the variable gasoline compression ratio. 2.57 percent of the gas utilized in the petrol engine, 2.60 percent, and 2.74 percent of HHO, the compression ratio was 7, 8 and 9. The investigation revealed that the fuel consumption dropped, and the compression ratio increased by the percentage of HHO gas. Thermal braking efficiency also boosted, as the HHO gas and compression ratio was raised by percent.

2.2.1 Generation of HHO Gas

HHO gas, called brown gas, is derived by water electrolysis. If the electrolyte used is a basic solution like KOH, there will be an alkaline response. In an alkaline reaction, the cathode reduction process occurs when the water molecule attaches electrons (e-) to hydrogen gas (H_2) and OH anions. The OH-anion is drawn to the side of the anode and divided into oxygen gas and H_2O molecules. Hydrogen gas possesses various colorless, combustible, extremely light qualities and is extremely simple to react to other compounds. However, HHO gas will not burn on its own without fire under typical settings. By considering the effective surface of electrodes, the efficiency of electrolysis devices may be enhanced. Therefore, the available current may be decreased when electricity is supplied to the electrode (Alam and Pandey, 2021).

Water electrolysis creates a hydrogen mixture, oxygen, and ions. The potential difference between electrodes relies on the quantity of gas produced per unit time. The responses at the electrodes are shown below (Neagu et al., 2000; Zeng and Zhang, 2010):

At cathode: $2H_2O + 2e \longrightarrow H_2 + 2OH^-$

At anode: $4OH^- \longrightarrow O_2 + 2H_2O + 4e$

Overall reaction: $2H_2O \longrightarrow 2H_2 + O_2$

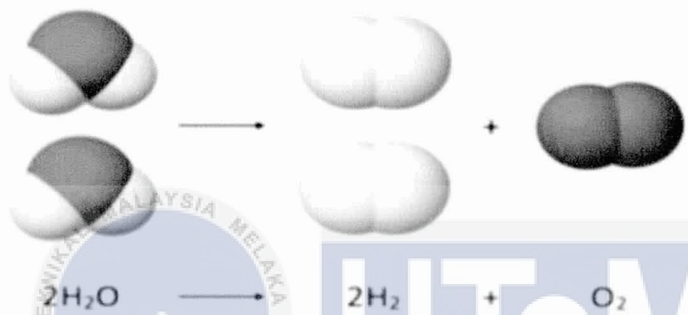

Figure 2.1 Decomposition into HHO Gas of water molecules (Sudarmanta et al.,2016)

Water in the anode interacts to create oxygen and hydrogen positive ions (protons). The electrons travel via an external system, and the hydrogen ions migrate selectively via the Polymer Electrolyte Membrane (PEM) to the cathode. In the cathode, hydrogen ions are combined with external circuit electrons to generate hydrogen gas. Water is electrolyzed by passing an electric current through it and then back to the electrodes (cathode and anode). It's possible that the electrolysis process will get going quickly. As a catalyst, water is mixed with a liquid electrolyte. As a voltage source to the water to be electrolyzed, the electrode serves as a conductor of electric current. When using DC current for electrolysis, the electrodes are split into two poles: the anode is positive, and the cathode is negative. Choosing an electrode material that has both electrical conductivity and high corrosion resistance is critical since HHO gas production from water electrolysis is affected by the electrode material. (Sudarmanta *et al.*,2016).

2.2.2 Effect of HHO Gas on Engine Performance

In general, fuel efficiency is improved, and the combustion process only completes if an internal combustion (IC) engine operates on a slim blend. In comparison to all other fuels, hydrogen has a broad spectrum of flammability. In an IC engine, hydrogen may thus be consumed across a variety of air-fuel ratios. This is also beneficial as hydrogen may be used on a leaner air-fuel combination, which assures quick igniting (Patil et al., 2017).

In their research paper, Patil et al., 2017 stated that HHO gas was produced as an electrolyte by the Potassium Hydroxide (KOH) water electrolysis method. Four-stroke, single-cylinder gasoline engine was employed as a supplementary fuel for performance testing with HHO gas supplied through the air intake. The performance was achieved using the variable gasoline compression ratio. 2.57 percent of the gas utilized in the petrol engine, 2.60 percent, and 2.74 percent of HHO, the compression ratio was 7, 8 and 9. The investigation revealed that the fuel consumption dropped, and the compression ratio increased by the percentage of HHO gas. Thermal braking efficiency also boosted, as the HHO gas and compression ratio was raised by percent.

In addition, the well-to-wheel study has shown that hydrogen-powered cars use minimal fuel usage and generate minimal greenhouse gases through the whole cycle (Jain et al., 2016). HHO gas may also be used as an additive and fuel to minimize emissions (Shahad and Abdul-Hadi, 2011). The most promising of the several possible alternative fuels is hydrogen because of its clean-burning and superior combustion qualities (Nanthagopal et al., 2011; Chaiwongsa et al., 2009). Common pipe water electrolyzers that can produce hydrogen oxygen mixing for injection into IC engines are mainly pushed as braking thermal efficiency techniques and fuel consumption and emissions reduction (Patil et al., 2017).

2.3 Biodiesel Fuel

The world is sliding toward an energy crisis due to the depletion of fossil resources. Moreover, the rapid increase in the usage of fossil fuels promotes this depletion. In addition, the growing price of fossil fuel, greenhouse gas emissions, safety and energy diversity is making scientists focus on finding alternate sources of fuel. Biodiesel is one of the finest alternative fuel sources (Basha et al., 2009). It is a renewable and clean fuel for diesel engines (Wu et al., 2009). It is also called environment friendly as it is non-toxic, biodegradable, safer to breathe and emits fewer greenhouse gases (McCarthy et al., 2011)

Biodiesel combines mono-alkyl esters of long-chain fatty acids (FAME) generated from a renewable lipid feedstock such as vegetables or animal fat as the alternative fuel for internal combustion engines. Biodiesel mainly consists of short-chain alcohol esters (C14–C22 chain lengths), predominantly methanol or ethanol (Demirbas, 2009). Biodiesel is the finest diesel fuel candidate in diesel engines. Biodiesel production is not a contemporary innovation. Rudolf Diesel's first diesel engine was manufactured using groundnut oil in 1900 (Murugesan et al., 2009). Rudolf Diesel also said in 1912 that vegetable oils would become a major fuel like petroleum in the future (Babu and Devaradjane, 2003). Awareness of the environment is making the prophecy of Rudolf Diesel a reality today (Murugesan et al., 2009).

For more than 100 years after the advent of the diesel engine, vegetable oils are employed as an alternative fuel (Shay, 1993). Depending on the ecological state, the source of biodiesel vary nation after country, such as North American soybean, sunflower and rapeseed for Europe, Southeast Asian palm, tropical and subtropical coconut, etc. (Murugesan et al., 2009a). However, the viscosity, heating, freezing point etc., of crude vegetable oils are less than fuel. Various chemical treatments such as transesterification may enhance the fuel characteristics. Transesterified vegetable oils are now extensively utilized (Meher et al., 2006)