

Technological Socio-economic and Eco (TSEE) friendly two-stroke LPG hydrogen engine

Submitted in partial fulfillment of the requirement for the award of
Bachelor of Engineering Degree in Mechanical Engineering

By

MUNNALURI BADREENATH (39150087)

NARAHARI SAI SRI HARI (39150090)



DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade “A” by NAAC | 12B Status by UGC | Approved by AICTE

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

APRIL – 2023



SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Accredited with “A” grade by NAAC
Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600 119
www.sathyabama.ac.in**

DEPARTMENT OF MECHANICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **MUNNALURI BADREENATH (39150087)** and **NARAHARI SAI SRI HARI (39150090)** who carried out the project entitled “**Technological Socio-economic and Eco (TSEE) friendly two stroke LPG hydrogen engine**” under our supervision from June 2022 to April 2023.

Internal guide

Dr. J. JAYAPRABAKAR, M.E., Ph.D.,

Head of the Department

Dr. G. ARUN KUMAR, M.E., Ph.D.,

Submitted for Viva voice Examination held on 26.04.2023

Internal Examiner

Dr.J.Hemanandh, M.E., Ph.D.,

External Examiner

Dr.J.Jayaprabakar, M.E., Ph.D.,

DECLARATION

We, **MUNNALURI BADREENATH (39150087)** and **NARAHARI SAI SRI HARI (39150090)**, hereby declare that the Project Report entitled “**Technological Socio-economic and Eco (TSEE) friendly two stroke LPG hydrogen engine**” done by me under the guidance of **Dr. J. JAYAPRABAKAR** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in **Department of mechanical engineering**.

1. 
2. 

DATE: 26.04.2023

PLACE: CHENNAI

SIGNATURE OF THE CANDIDATES

ACKNOWLEDGEMENT

We are pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

We convey our thanks to **Dr. S. PRAKASH**, Dean, School of Mechanical Engineering, and **Dr. G. ARUN KUMAR**, Head, Department of Mechanical Engineering for providing us with necessary support and details at the right time during the progressive reviews.

We would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. J. JAYAPRAKAS** for his valuable guidance, suggestions, and constant encouragement that paved the way for the successful completion of my project work.

We wish to express our thanks to all Teaching and Non-teaching staff members of the **DEPARTMENT OF MECHANICAL ENGINEERING** who were helpful in many ways for the completion of the project.

ABSTRACT

In the present scenario, low-emission vehicles are promoted almost all over the world. In every aspect of energy transformation systems clean process is required. IC engines emit a considerable amount of pollutants and contribute to global warming. Both SI and CI engines contribute to emissions to the atmosphere. There are many methods adopted for reducing emissions from SI engines. Two-stroke SI Engines are theoretically producing double the power of 2 strokes CI engines but these are banned because of their serious emission levels.

LPG and HHO Gas are used in this study to mitigate the emission from the 2-stroke SI 2-stroke. In this work, an aa2-stroke a2-stroke is modified to have Petrol or LPG as Dual fuel mode operation with HHO Gas. HHO gas is produced by means of a simple electrolyser kit that uses a battery current. The fuel tank is modified so as to have either LPG or Petrol at a particular instance. The modified fuel tank is fitted in a Two-wheeler bike and the bike is tested for its mileage and CO and HC emissions.

TABLE OF CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
	ABSTRACT	V
	LIST OF TABLES	VIII
	LIST OF FIGURES	VIII
	LIST OF ABBREVIATIONS	IX
1	INTRODUCTION	1
	1.1 HISTORY AND BACKGROUND OF CLEAN ENERGY	1
	1.2 REQUIREMENT OF CLEAN ENERGY	2
	1.3 CAUSES OF POLLUTION	4
	1.4 POLLUTION IN SI AND CI ENGINES	4
	1.4.1 POLLUTION IN SI ENGINES	5
	1.4.2 POLLUTION IN CI ENGINES	6
	1.5 REDUCING EMISSIONS IN SI ENGINES	6
	1.5.1 LPG	6
	1.5.1.1 BENEFITS OF LPG	7
	1.5.2 HYDROXYL GAS	8
	1.5.2.1 BENEFITS OF HYDROXYL GAS	9
2	LITERATURE SURVEY	11
3	AIM AND SCOPE	14
	3.1 AIM	14
	3.2 SCOPE	14
4	MATERIALS AND METHODOLOGY	15
	4.1 LPG KIT	15
	4.2 ELECTROLYSIS KIT	16

	4.3 LPG REGULATOR	17
	4.4 SOLENOID VALVE	18
	4.5 METHODOLOGY	19
5	RESULTS AND DISCUSSION	20
	5.1 LAYOUT OF THE FABRICATED BIKE DESIGN	20
	5.2 MODIFIED BIKE	21
	5.2.1 MODIFIED FUEL TANK	22
	5.2.2 LPG KIT AND ELECTROLYSIS KIT	22
	5.2.3 LPG INLET AND REGULATOR	23
	5.3 COMPURITISED POLLUTION TESTING REPORTS	23
	5.3.1 POLLUTION REPORT FOR PETROL	24
	5.3.2 POLLUTION REPORT FOR PETROL + HYDROGEN	24
	5.3.3 POLLUTION REPORT FOR LPG	25
	5.3.4 POLLUTION REPORT FOR LPG + HYDROGEN	25
	5.4 EMISSION RESULTS	26
	5.4.1 EMISSION VALUES FOR CARBON MONOXIDE	26
	5.4.2 EMISSION VALUES FOR HYDROCARBON	26
	5.5 EMISSION TESTING VALUES	27
6	SUMMARY AND CONCLUSION	28
	REFERENCES	29

LIST OF TABLES

TABLE NO	TITLE	PAGE NO
1.1	BENEFITS OF LPG	7
1.2	BENEFITS OF HYDROXYL GAS	9
5.1	EMISSION VALUES	27

LIST OF FIGURES

FIGURE NO	TITLE	PAGE NO
4.1	LPG KIT	15
4.2	ELECTROLYSIS KIT	16
4.3	LPG REGULATOR	17
4.4	SOLENOID VALVE	18
4.5	METHODOLOGY	19
5.1	FABRICATED BIKE DESIGN LAYOUT	20
5.2	MODIFIED BIKE ON LEFT SIDE	21
5.3	MODIFIED BIKE ON RIGHT SIDE	21
5.4	MODIFIED FUEL TANK	22
5.5	LPG KIT AND ELECTROLYSIS KIT	22
5.6	LPG INLET AND REGULATOR	23
5.7	POLLUTION REPORT FOR PETROL	24
5.8	POLLUTION REPORT FOR PETROL + HYDROGEN	24
5.9	POLLUTION REPORT FOR LPG	25
5.10	POLLUTION REPORT FOR LPG+HYDROGEN	25
5.11	EMISSION OF CARBON MONOXIDE	26
5.12	EMISSION OF HYDROCARBON	26

LIST OF ABBREVIATIONS

HHO - HYDROXYL GAS

LPG - LIQUEFIED PETROLEUM GAS

SI - SPARK IGNITION

CI - COMPRESSION IGNITION

CO - CARBON MONOXIDE

HC - HYDROCARBONS

NOX - NITROGEN OXIDES

CO₂ - CARBON DIOXIDE

SO₂ - SULPHUR DIOXIDE

HO - WAT

CHAPTER 1

INTRODUCTION

1.1 HISTORY AND BACKGROUND OF CLEAN ENERGY

Clean energy has gone a long way, but there are still obstacles to be addressed. The development of energy storage technologies is necessary to maintain a dependable and steady supply of energy due to the intermittent nature of various renewable energy sources, such as wind and solar power. Clean energy infrastructure, including transmission lines and storage facilities. The history of sustainable energy is lengthy and goes back thousands of years. It is a crucial part of the transition to a future that is more ecologically friendly and sustainable. Renewable energy is becoming more accessible and competitive with fossil fuels because of the quick advancement of new technology and its falling cost of it. To secure a stable and sustainable energy future, further research and development are required as there are still obstacles to be solved. José Goldemberg (2006)

Water is electrolyzed to create hydroxyl gas, commonly referred to as HHO gas or Brown's gas, the combination of hydrogen and oxygen gases. Although the utilizing HHO gas as a fuel additive in diesel and petrol engines has been around for a while, there have been questions about how effective it is as a fuel. HHO gas has been researched in the context of two-stroke spark ignition (SI) engines, for example. Mopeds, scooters, and small boats frequently employ two-stroke engines, which are also well-recognized for their heavy exhaust emissions. By employing HHO gas in two-stroke engines, it is hoped that emissions would be reduced and fuel economy will be increased. Hydrogen and oxygen gases are combined to form hydroxyl gas, commonly referred to as HHO gas, which is created by the electrolysis process. A long time ago, there have been several experimental studies concerning the feasibility of utilizing HHO gas as a fuel for internal combustion engines. Dincer, Ibrahim; Acar, Canan (2015)

The use of HHO gas in two-stroke spark ignition (SI) engines, which are often used in small vehicles like motorcycles and scooters, has been the subject of some studies. With one power stroke per two crankshaft rotations, two-stroke engines have a simpler

operating cycle than four-stroke engines. Yet, two-stroke engines are infamous for producing large amounts of particulate matter, carbon monoxide, and hydrocarbon pollutants. Lowitzsch J; Hoicka C.E.; van Tulder, F.J. (2020)

In order for the engine to run on gasoline mixes, the increasing interest in and worry over clean energy. It is a crucial part of the transition to a future that is more ecologically friendly and sustainable. The background and history of clean energy are strongly connected with the progression of human civilisation. When people first started using wind and water power to mill grains and other things thousands of years ago, clean energy was being used. Jones, Aled W. (2015).

Clean energy technology has been rapidly adopted in the twenty-first century. Renewable energy is now more affordable than fossil fuels, making it more competitive. The transition to a low-carbon economy has lofty targets that governments and businesses throughout the world have set. Compared to fossil fuels, clean energy provides a number of advantages. It is a plentiful, renewable energy source that doesn't emit greenhouse gases. It may be produced and used locally because of its decentralized nature, which eliminates the need for energy to be transported across great distances. If nations may rely on their own energy sources rather than importing from other nations, clean energy can help enhance energy independence and security. Mitrašinović, A. M(2021)

1.2 REQUIREMENT OF CLEAN ENERGY

As we struggle to cut down greenhouse gas emissions and the consequences on climate change, renewable energy is becoming more and more crucial in today's society. The energy that originates from renewable sources and emits little to no toxic emissions is referred to as "clean energy." The need of clean energy has been clearer in recent years due to the negative impacts of climate change and air pollution on the environment and human health. To make the shift to a sustainable future, it's essential to follow certain clean energy criteria. a few of the most important criteria for clean energy in the present day include the following Stern, Alvin G. (2018).

- ❖ Renewable energy sources: Using clean energy requires the utilization of renewable energy sources including the sun, wind, hydropower, and geothermal energy. Renewable energy sources are long-lasting, emit little pollution, and don't run out over time. To replace fossil fuels, governments, and

businesses must make investments in the creation and application of renewable energy technology. Surendra Kothari (2011)

- ❖ Energy efficiency: Increasing energy efficiency is a crucial component of a sustainable energy future. Using energy-efficient building design, technology, and behavioral changes, energy efficiency techniques aim to reduce energy usage. Enhancing energy efficiency may lower greenhouse gas emissions, save customers money, and preserve energy.
- ❖ Carbon capture and storage: The process of storing subterranean carbon dioxide emissions from industrial processes and power plants is known as carbon capture and storage. Carbon capture and storage is an essential part of renewable energy because it can reduce emissions from fossil fuel power plants, which still produce a sizable portion of the world's electricity.
- ❖ Electric automobiles: The transportation industry contributes significantly to emissions of greenhouse gases. An essential prerequisite for renewable energy is the deployment of electric vehicles. Electricity used to power EVs may be produced from renewable resources. The deployment of electric vehicles can enhance sustainable mobility and dramatically lower transportation-related emissions.
- ❖ Smart grids: Smart grids are cutting-edge energy networks that make it possible to integrate renewable energy sources and control the supply and demand for power in real time. Clean energy needs smart grids because they can assist balance power supply and demand and provide a dependable and sustainable energy system.
- ❖ Green hydrogen is hydrogen that has been created using sustainable energy sources and is suitable for a range of uses. In order to decarbonize industrial processes and the transportation sector, green hydrogen must be created from renewable water and electricity sources.
- ❖ Storage of energy: Energy storage is a crucial prerequisite for renewable energy. As excess renewable energy becomes available, it is released until it is required. Energy storage can help the system absorb sporadic renewable energy sources and provide a steady and predictable electricity supply. Kim, Young-Min (2012)

1.3 CAUSES OF POLLUTION

Whenever fossil fuels are burned incompletely, which causes the emission of hazardous pollutants into the atmosphere. The main causes of CI and SI engine emissions are as follows:

- ❖ Incomplete Combustion: - Pollutants including carbon monoxide, hydrocarbons, and particulate matter are released when in fuel-air combination is not entirely burnt. Vignesh, R. (2022).
- ❖ Fuel Quality: - The degree of emissions is significantly influenced by the quality of the fuel used in engines. Pollutant emissions may be increased by using fuels of poor quality or that has been tainted.
- ❖ Engine Design: - Pollution can also result from engine design. It's possible that older engines lack cutting-edge emission control systems, leading to increased pollution emissions. Yusaf, T. (2021).
- ❖ Engine Maintenance: - Engines that are not properly maintained might emit more pollution. The engine's performance is based on regular maintenance.
- ❖ Driving Behaviour: - Emissions also depend on how a vehicle is driven. Higher emissions of pollutants can be the result of aggressive driving, such as rapid acceleration and abrupt braking.

1.4 POLLUTION IN SI AND CI ENGINES

The release of different contaminants during the combustion process is the main source of pollution from internal combustion engines, regardless of whether they are compression-ignition (CI) or spark-ignition (SI) engines. These engines mostly emit hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM), and carbon dioxide (CO₂). Moreover, greenhouse gases like carbon dioxide (CO₂), which aid in climate change, are released by both SI and CI engines. The increase in atmospheric (CO₂) concentrations is mostly caused by the combustion of fossil fuels in these engines. Several methods, including the use of emission control technology like catalytic converters, diesel particle filters, and selective catalytic reduction systems, have been put into place to address these pollution issues. Apart from that, cleaner fuels have been developed, such low-sulfur gasoline and diesel. Akansu, S. O. (2022)

1.4.1 POLLUTION IN SI ENGINES

Air pollution caused by spark-ignition (SI) engines is a major environmental concern. SI engines are widely used in automobiles, motorcycles, lawn mowers, and other small engines. Carbon monoxide (CO), a colourless and odourless gas that is hazardous in high amounts, is one of the principal pollutants released by SI engines. Incomplete combustion of the fuel-air combination in an engine results in the production of CO. When the air and fuel are not correctly combined or when there is not enough oxygen in the combustion chamber, this can happen. By optimizing engine design, ensuring adequate fuel injection and air movement, and utilizing catalytic converters, CO emissions may be decreased. Another significant pollutant released by SI engines is nitrogen oxides (NO_x). Awad omar (2018)

NO_x is created when air molecules of nitrogen and oxygen react at the high temperature of the combustion chamber. NO_x may be unhealthy and leads to the development of smog and acid rain. Engine makers have created novel technology like selective catalytic reduction and exhaust gas recirculation to lower NO_x emissions. SI engines also produce a lot of particulate matter, which is a serious pollutant. PM is made up of microscopic particles that, when breathed, can lead to respiratory troubles as well as other health concerns. Diesel engines release the majority of particulate matter (PM), however under some circumstances, petrol engines can as well. Diesel particulate filters have been created by engine manufacturers in order to lower PM emissions. Hydrocarbons (HC) are another gas that SI engines release. Unburned fuel and other organic chemicals are included in the group of substances known as HC. Sher, E. (1998)

By enhancing engine design, utilizing electronic fuel injection systems, and ensuring that the engine is properly maintained, HC emissions can be decreased. SI engines release a variety of air pollutants, including those that contribute to acid rain, climate change, and respiratory issues. SI engines are a substantial source of air pollution. Engine makers have created new technology and laws to increase engine efficiency and minimize hazardous emissions in order to lessen these pollutants. To further lessen the negative effects of SI engines on the environment, however, additional

research and development are required. Reduced emissions from SI engines may also be achieved via proper maintenance of engines and vehicles. Ravi,k (2017)

1.4.2 POLLUTION IN CI ENGINES

Heavy vehicles including trucks, buses, trains, generators, and other equipment, frequently employ compression-ignition (CI) engines. Many pollutants that these engines are known to release into the atmosphere and contribute to climate change. Nitrogen oxides are a significant contaminant released by CI engines (NO_x). NO_x may be unhealthy and leads to the development of smog and acid rain. Engine makers have created novel technology like selective catalytic reduction and exhaust gas recirculation to lower NO_x emissions. Sangeetha.M (2022)

CI engines also release carbon monoxide (CO), which is created when the fuel-air combination in the engine burns insufficiently. When there is insufficient oxygen in the combustion chamber or when the air and fuel are improperly combined, this can happen. By optimizing engine design, ensuring adequate fuel injection and air movement, and utilizing catalytic converters, CO emissions may be decreased. CI engines also generate sulfur dioxide (SO₂) and hydrocarbons (HC), 1 By adopting electronic fuel injection systems, enhancing engine design, and ensuring that the engine is properly maintained, HC emissions can be decreased. Using low-sulfur diesel fuel will lower emissions of sulfur dioxide. In CI engines, the major pollutants emitted are nitrogen oxides (NO_x), PM, CO, and HC

1.5 REDUCING EMISSIONS IN SI ENGINES

The adverse effects of emissions from Spark-Ignition (SI) engines on the environment and human health have become a rising source of concern in recent years. To reduce these pollutions, explore alternative fuel sources, such as Liquefied Petroleum Gas (LPG) and Hydroxyl Gas (HHO), as potential replacements for conventional gasoline.

1.5.1 LPG

Compared to petrol, LPG burns cleaner and produces less emissions. Since gasoline has a higher rating in octane, it may be used to boost the compression ratio of SI engines, which will increase their efficiency and reduce their emissions. In addition,

LPG has a lower carbon content than gasoline, In addition, LPG has a greater hydrogen content, which when used in an engine can result in fewer nitrogen oxide (NOx) emissions. Bayraktar, H., & Durgun, O. (2005).

1.5.1.1 BENEFITS OF LPG

The investigation of alternative fuel sources, such as Liquefied Petroleum Gas, is being driven by the growing concern about the effects of pollutants from Spark-Ignition (SI) engines on the environment and human health (LPG). When compared to regular petrol, LPG has a number of advantages due to its cleaner burning characteristics. The lower carbon content of LPG, which leads in less carbon dioxide and carbon monoxide being released when burned, is one of its main advantages. Moreover, LPG emits fewer nitrogen oxides (NOx) when utilised in an engine because to its greater hydrogen content. LPG is a commonly available fuel source and has various advantages over other fuels for SI engines, including lower emissions of pollutants, increased efficiency, and lower fuel consumption. But switching to LPG as a fuel source necessitates alterations to the engine and fuel distribution system, as well as the installation of the necessary safety precautions to avoid mishaps. Steenland, (2018)

TABLE 1.1 BENEFITS OF LPG

SL.NO	PROPERTY/BENEFITS	DESCRIPTION
1	Chemical composition	LPG (Liquefied Petroleum Gas) is a mixture of propane and butane gases
2	Flammability	LPG is highly flammable and can be used as a fuel source
3	Clean burning	LPG burns more cleanly than traditional fuels, producing less carbon dioxide, nitrogen oxide, and particulate matter
4	Energy efficiency	LPG has a high energy content per unit of volume and burns more efficiently than traditional fuels, resulting in lower fuel consumption and cost savings
5	Versatility	LPG is used in a variety of applications, including heating, cooking

6	Storage	LPG is stored in a liquid state, making it more compact and easier to transport and store than traditional
7	Safety	LPG is stored under pressure and can be dangerous if not handled properly, as it can cause fires and explosions
8	Availability	LPG is widely available and can be easily sourced from a variety of suppliers
9	Environmental Benefits	LPG produces fewer greenhouse gas emissions than traditional fuels, making it a more Environmental environmentally friendly alternative
10	Cost saving	LPG can be more cost-effective than traditional fuels, especially in areas where natural gas is not available or where electricity costs are high

1.5.2 HYDROXYL GAS

A combination of hydrogen and oxygen called hydroxyl gas (HHO) is created when water is electrolyzed. HHO can increase combustion efficiency and lower emissions when it is added to a SI engine. Carbon monoxide, hydrocarbons, and nitrogen oxide emissions can be reduced by using HHO because it can promote more thorough combustion of the fuel-air combination.

The use of LPG and HHO in SI engines may significantly reduce the number of pollutants released into the environment. The engine and fuel distribution system must be changed in order to use these alternate fuels, though. For instance, a separate fuel system is needed for LPG than for gasoline, and an electrolysis system must be installed to make HHO. Aidyin.k (2010)

1.5.2.1 BENEFITS OF HYDROXYL GAS (HHO)

For internal combustion engines, hydroxyl gas (HHO) has been proposed as a fuel addition with a number of possible advantages. Hydrogen and oxygen are combined to form the gas known as HHO when water is electrolyzed. Here are a few advantages of use HHO:

TABLE 1.2 BENEFITS OF HYDROXYL GAS

Sl. no	Property/ Benefit	Description
1	Chemical formula	HO (water) is electrolyzed into H: (hydrogen) and O (oxygen) gases
2	Flammability	Hydroxyl gas is highly flammable and can be used as a fuel source
3	Clean burning	When used as a fuel, hydroxyl gas produces only water vapor as a by-product, making it a clean-burning fuel source
4	Efficiency	Hydroxyl gas has a higher energy density than traditional fuels, meaning it can produce more energy per unit of volume
5	Safety	Hydroxyl gas can be dangerous if not handled properly, as it is highly flammable and explosive
6	Applications	Hydroxyl gas is used in a variety applications, including welding, cutting, brazing, and beating
7	Environmental benefits	When used as a fuel source, hydroxyl gas produces no greenhouse gas emissions, making it an environmentally friendly alternative to traditional fuels
8	Cost savings	The uses in hydroxyl gas as a fuel source can result in cost savings, as it can be produced on-site and eliminates the need for fossil fuels
9	Research and development	research and development is exploring new and innovative applications for hydroxyl gas, highlighting its potential use in fuel cell and solar cell technologies for renewable energy

- ❖ HHO is introduced to the engine's air/fuel combination, where it combines with the gasoline or diesel fuel to provide a more thorough and efficient combustion process. This leads to increased fuel economy, which can lower greenhouse gas emissions and lower fuel costs. Setyono, G. (2020)
- ❖ Carbon monoxide, nitrogen oxides, and hydrocarbon emissions can all be decreased because of the better combustion process made possible by HHO (HC). This may result in healthier individuals and the environment as well as cleaner air.
- ❖ Improved performance and acceleration: By incorporating HHO into the combustion process, the engine's power output may also be increased.
- ❖ Simple to produce on demand: HHO may be produced on demand using an electrolysis machine, negating the need for substantial storage facilities or pipelines. This gives it a fuel source that is more mobile and adaptable.
- ❖ Sustainable energy sources, solar and wind power, may be used to electrolyze water, which produces HHO. This suggests that HHO has the potential to be an environmentally friendly fuel source that can help to lessen dependency on fossil fuels. Tüccar, G. (2018)
- ❖ It is significant to remember that using HHO has certain restrictions and difficulties as well. These costs include the expense of the machinery required to produce and inject HHO into the engine as well as the requirement for appropriate safety measures to prevent mishaps or engine damage. Also, the efficiency improvements and pollution reductions brought about by HHO may differ based on the kind of engine, fuel, and operating circumstances. Patil, S. E. (2016)
- ❖ In the present study an attempt has been made to use alternative fuel for the 100cc 2-stroke engine as we know the present need for clean energy fuels and the requirement of clean energy. Now a days we all know that the pollution is more and more in motor vehicles to reduce the emissions in 2 stroke 100cc engine one attempt has been made and going to make a fabricated design .in this design we are going to add external LPG and HHO kit for the engine to reduce the emissions, while adding this both kits we are able to reduce the emissions as before. Aydin, K., & Kenanoğlu, R. (2018)

CHAPTER 2

LITERATURE SURVEY

J.O.Abe., (2014) Hydrogen energy, economy and storage: Review and recommendation by discusses the potential of hydrogen as a sustainable energy carrier and storage medium, as well as its economic and societal implications. The article provides recommendations for policy-makers and researchers to promote the development of a hydrogen economy.

Sergey P., (2008) Hydrogen energy development prospects and materials by - the current state of hydrogen energy development and its future prospects. The article may also explore the materials and technologies that are necessary for the production, storage, and use of hydrogen as an energy source.

Haris Ishaq., (2018) A review on hydrogen production and utilization: challenges and opportunities the current state of hydrogen production and utilization, as well as the challenges and opportunities associated with this promising energy carrier. The article highlights the various methods of hydrogen production, including steam methane reforming and electrolysis, and discusses potential applications such as transportation and energy storage.

Mohammad Sabeghi., (2015) Experimental study of the effect of HHO gas injection on pollutants produced by a diesel engine at idle speed. This experimental study would investigate the effect of HHO gas injection on pollutants produced by a diesel engine at idle speed. It would involve selecting an appropriate engine and HHO generator, and setting up an experimental setup to measure pollutant emissions with and without HHO gas injection. The study would provide insights into the potential of HHO gas injection to reduce diesel engine emissions at idle speed.

Venugopal Thangave., (2014) Investigations on the effect of H₂ and HHO gas induction on brake thermal efficiency of dual-fuel CI engine. The effect of H₂ and HHO gas induction on brake thermal efficiency of a dual-fuel compression ignition (CI) engine. The study aims to determine the optimal conditions for gas induction to improve engine efficiency, which could lead to reduced emissions and improved fuel economy. The results of the investigation could have significant implications for the

development of more efficient and environmentally-friendly internal combustion engines.

Zhe Zhao., (2016) effect of brown gas (HHO) addition on combustion and emission in gasoline engine with exhaust gas recirculation (EGR) and gasoline direct injection by - the effect of brown gas (HHO) addition on combustion and emissions in a gasoline engine with EGR and GDI. The study involves selecting a suitable engine and HHO generator, setting up an experimental apparatus, and conducting testing it procedures to measure engine performance and emissions. The results of the investigation could provide insights into the potential of HHO gas injection to reduce emissions and improve engine efficiency in gasoline engines with EGR and GDI Systems

Hariprasad Tarigonda., (2019) Optimization of performance and emission characteristics of a diesel engine in dual-fuel mode with LPG using adaptive-neuro fuzzy inference system model by Hariprasad Tarigonda - This study aims to optimize the performance and emission characteristics of a diesel engine in dual-fuel mode with LPG, using an adaptive-neuro fuzzy inference system (ANFIS) model. The methodology involves selecting a suitable diesel engine, collecting performance and emissions data, developing the ANFIS model, and using it to optimize engine performance and emissions. The study could provide insights into the potential of ANFIS modeling to improve the efficiency and reduce emissions of dual-fuel engines.

Ajay Vardhan., (2017) Performance and Emission Analysis of Modified Compression Ignition Engine from Diesel Engine to Variable Load using Petrol and LPG Fuel the performance and emissions of a modified compression ignition engine using petrol and LPG fuel at variable loads. The methodology involves modifying the engine for dual-fuel operation, setting up an experimental apparatus, and conducting fuel testing to measure engine performance and emissions.

Muhammad Usman., (2012) Use of Gasoline, LPG and LPG-HHO Blend in SI Engine: A Comparative Performance for Emission Control and Sustainable Environment - aims to compare the performance and emissions of gasoline, LPG, and LPG-HHO blends in an SI engine for emission control and sustainable environment. The methodology involves selecting a suitable engine, preparing different fuel blends, setting up an experimental apparatus, and measuring engine performance and emissions.

Hakan Ozcan., (2011) Effects of Hydroxy Gas Addition on the Performance and Emission Characteristics of Liquefied Petroleum Gas-Powered Lean-Operated Spark-Ignition Engine. The effects of hydroxy gas addition on the performance and emission characteristics of a lean-operated, LPG-powered spark-ignition engine. The methodology involves installing a hydroxy gas generator, setting up an experimental apparatus, and conducting testing procedures to measure engine performance and emissions.

D.B. Lata., (2013) Effect of hydrogen and LPG addition on the efficiency and emissions of a dual fuel diesel engine, the effect of hydrogen and LPG addition on the efficiency and emissions of a dual fuel diesel engine. The methodology involves View Help installing a hydrogen and LPG system, setting up an experimental apparatus, and conducting testing procedures to measure engine performance and emissions.

In this assessment of the literatures, we examined publications on several alternative fuels and their potential to lower emissions and increase engine performance, including hydrogen and LPG. The papers covered the generation and use of hydrogen, the impact of HHO gas injection on diesel engine emissions, the impact of H₂ and HHO gas induction on a dual-fuel CI engine's braking thermal efficiency, and the impact of LPG on engine output and emissions. The majority of the articles point out that these alternative fuels have the potential to lower emissions and increase engine efficiency, but more study is required to fully understand how to use them. To lessen reliance on fossil fuels and advance the creation of a sustainable energy future, policymakers and academics should support the development of these alternative fuels. The investigation and experimentation of these alternative fuels can provide significant insights into their potential for reducing emissions and improving engine efficiency, and thus contribute to a cleaner and sustainable environment

CHAPTER 3

AIM AND SCOPE

3.1 AIM:

This research project's main goal is to experimentally examine the performance and emissions characteristics of two-stroke SI engines that run on hydroxyl gas/LPG and hydroxyl gas and petrol. The purpose of the study is to offer fresh perspectives on the viability of utilizing hydroxyl gas as a viable substitute fuel for regular petrol and LPG in two-stroke SI engines.

3.2 SCOPE:

This research project's scope includes carrying out extensive tests on a two-stroke SI engine with fuels such as hydroxyl gas/LPG and gasoline. Braking force, torque, and fuel consumption are among the performance metrics that need to be assessed, whilst carbon monoxide (CO), hydrocarbon (HC), and nitrogen oxide (NO_x) emissions are among the emissions parameters that need to be assessed. To examine the impact of various operating circumstances on engine performance and emissions, the tests will be run at a variety of engine speeds and loads. The obtained experimental results will be subjected to statistical analyses and compared with those obtained using conventional gasoline/LPG fuel. This research project aims to provide crucial insights into the potential of hydroxyl gas as an alternative fuel for two-stroke SI engines, This can lessen the need for traditional fossil fuels and greenhouse gas emissions. The results of this study might be a useful guide for creating greener, more sustainable engines for use in transportation and other applications.

CHAPTER 4

MATERIALS AND METHODS

4.1 LPG KIT

Vehicle owners who want to lessen their carbon impact and save their fuel expenses are becoming more and more likely to purchase LPG conversion kits. LPG conversion kits are to enable the use of LPG, cleaner-burning fuel, in standard gasoline engines. The decreased emission of pollutants is one of the main benefits of LPG conversion kits. Karamangil, M. I. (2007)

In addition to the environmental benefits, LPG kit offers cost savings, is very less expensive than gasoline, and results in lower fuel costs for motor vehicle owners, LPG combustion produces fewer carbon deposits on engine components than gasoline engines. Another important thing to notice in LPG kits is to take safety measures such as gas leaks and fire accidents. By using an LPG kit some benefits include reduced emissions of pollutants, lower fuel costs, and extended engine life. LPG conversion kits can be safe and effective to traditional gasoline engines. Setiyo, M., & Waluyo, B. (2019).

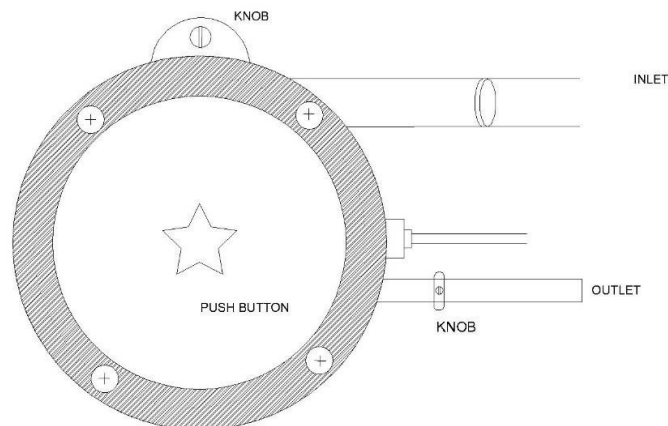


Fig 4.1 LPG KIT

4.2 ELECTROLYSIS KIT

HHO kits are with hydrogen and oxygen gas through electrolysis of water as a supplement to the gasoline engine. The increased fuel economy of HHO kits is one of its main benefits. Using HHO gas in addition to traditional fuel sources promotes more thorough combustion, which reduces fuel consumption and pollutant emissions. Patil, K (2016)

Additionally, the higher combustion temperature of HHO petrol leads to a cleaner engine and less carbon buildup on engine components. The usage of HHO kits can also enhance engine performance and make driving more comfortable. HO kits are easy to install and can be retrofitted by gasoline engines.

HHO kits are very beneficial to vehicle owners, including fuel efficiency, improved engine performance, and reduce emissions of pollutants, HHO kits are safe and effective alternatives to traditional gasoline engines. Sudhakaran (2014)

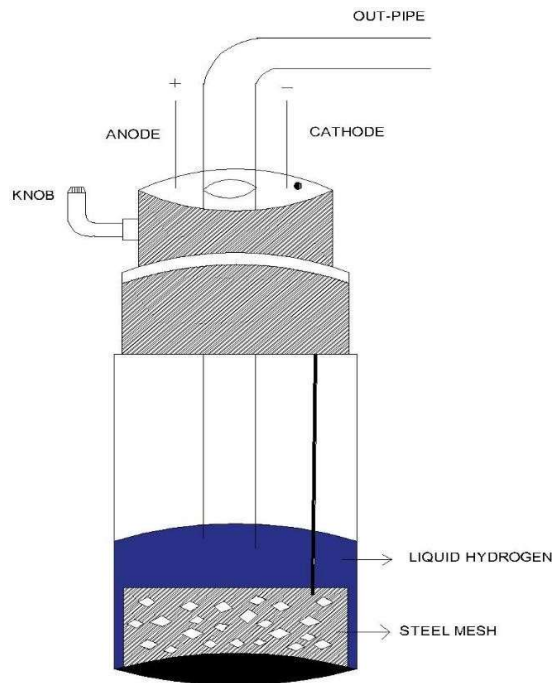


FIG 4.2 ELECTROLYSIS KIT

4.3 LPG REGULATOR

LPG regulators are a necessary component for LPG conversion kits for 100cc 2-stroke engines. This regulator will reduce the high-pressure LPG gas to a suitable pressure to use in the engine. The LPG regulator controls the supply to the engine according to the engine's need for fuel. Also, the regulator makes sure that the gas pressure never fluctuates. Güner, E. (2015).

The major benefit of employing an LPG regulator is that the LPG conversion kit is now much safer. The regulator makes sure that the gas pressure is as per need and keeps the gas tank from becoming over-pressurized, which might result in gas leaks and fires. LPG regulators contribute to the increased effectiveness of the LPG conversion kit in addition to the safety advantages. LPG regulators are relatively easy to install and can be retrofitted to most 100cc 2-stroke engines. The installation process involves the installation of the regulator, the necessary plumbing, and wiring.

LPG regulators are more beneficial to 100cc 2-stroke engine and it includes more safety, and efficiency and reduces emissions of pollutants. This LPG regulator can be more effective and safer with proper installation and maintenance. Ceviz, M. A., & Kaleli, A. (2015, October).

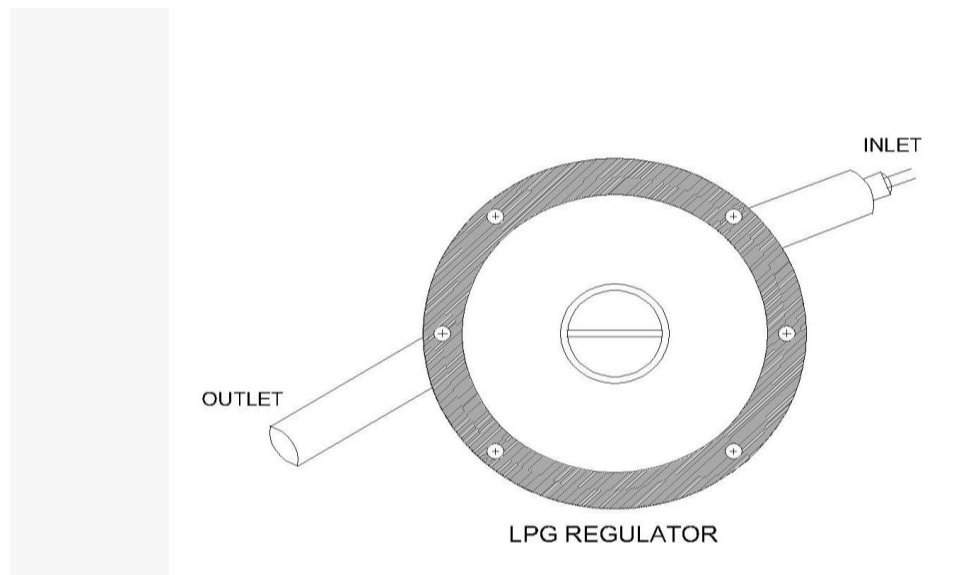


Fig 4.3 LPG Regulator

4.4 SOLENOID VALVE

The solenoid valve is a necessary component of an LPG kit for a 100cc 2-stroke engine. It is installed between the LPG cylinder and the engine to control the flow of LPG gas to the engine. The solenoid valve operates using a small motor that opens or closes the valve allowing or stopping the flow of LPG gas to the engine. The system's increased safety is one of the main benefits of employing a solenoid valve in an LPG conversion kit. When an engine fails or RPM suddenly drops, the valve can automatically close, stopping the release of LPG gas and lowering the risk of a fire or explosion. Moreover, solenoid valves can help the LPG conversion kit work more effectively. Kim, C. K., Lee, I. K., & Cho, S. H. (2011)

The engine will receive the ideal quantity of fuel necessary for peak performance thanks to the valve's ability to regulate the flow of LPG gas to the engine. This may result in fewer pollution emissions and fuel consumption. Additionally, most 100cc 2-stroke engines may be upgraded with solenoid valves since they are quite simple to install. Owners of 100cc 2-stroke engines might gain a lot from solenoid valves if they employ LPG conversion kits. They offer increased security, more effectiveness, and lower pollution emissions. Solenoid valves may be a secure and reliable part of LPG conversion kits for 100cc 2-stroke engines with correct installation and maintenance. Stoyanov, S. N., (2021).

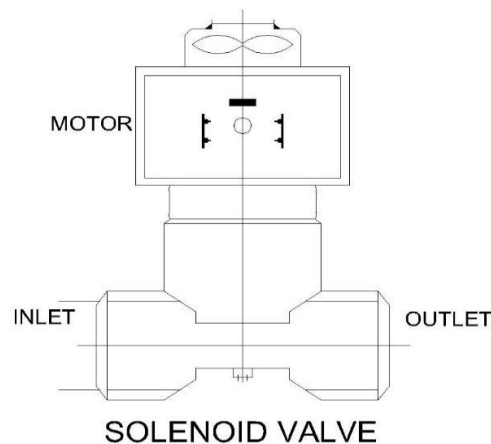


Fig 4.4 SOLENOID VALVE

4.5 METHODOLOGY

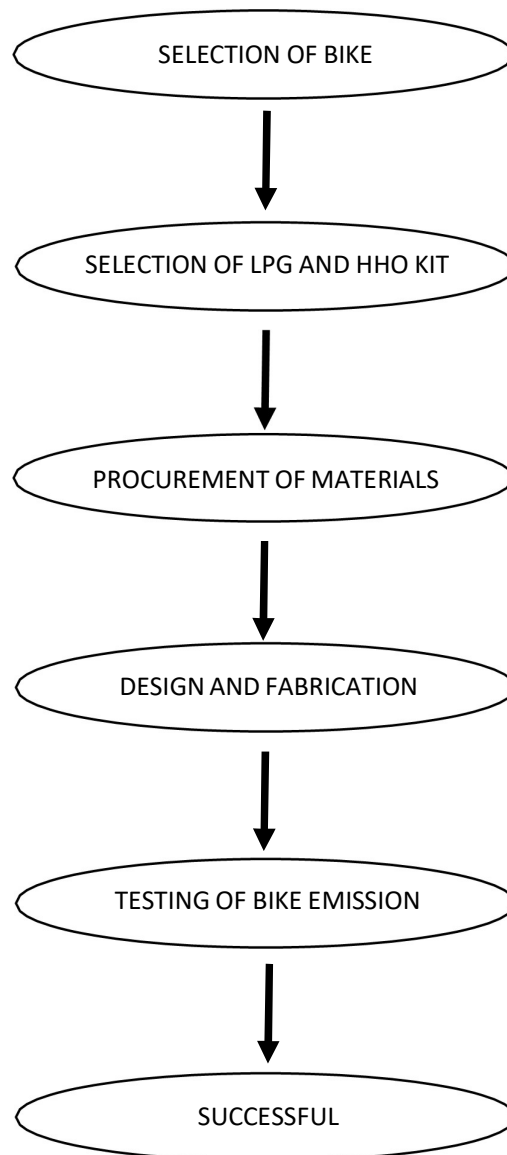


FIG 4.5 METHODOLOGY

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 LAYOUT OF THE FABRICATED DESIGN

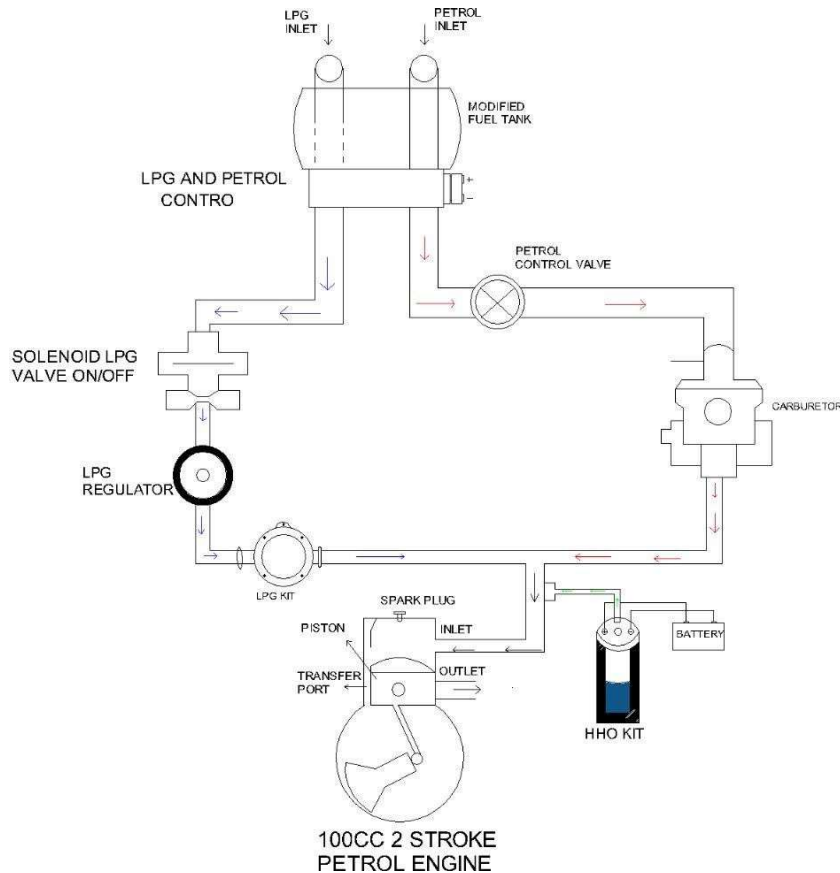


Fig 5.1 Fabricated design layout

The above layout represents the fabricated design and the working process of the engine, the modified fuel tank is containing the two types of fuels LPG and petrol, and the flow of both fuels can able to control with the LPG and petrol regulator switch while working on the fuel the flow of the petrol will pass through the carburetor and passes to the engine while it passes the hydrogen is added to the engine to reduce the emissions as we already know that when we switch into the LPG will flow into the regulator then the LPG regulator will control the flow of the LPG and passes it to the LPG kit then the LPG is passed to the inlet of the 100cc 2stroke engine while it entering

into the engine the hydrogen is also added to the engine this is the total working of the 100cc 2 stroke engine to reduce the emissions. Santram, B (2015)

5.2 MODIFIED BIKE



FIG 5.2 MODIFIED BIKE LEFT SIDE



FIG 5.3 MODIFIED BIKE RIGHT SIDE

5.2.1 MODIFIED FUEL TANK



Fig 5.4 Modified Fuel Tank

From the above image, we can notice some differences in the tank which we have done modifications, which is able to fill both petrol and LPG this is the uniqueness of the tank for our fabricated design.

5.2.2 LPG KIT AND ELECTROLYSIS KIT



FIG 5.5 LPG KIT AND ELECTROLYSIS KIT

From the above figure, we can see the LPG kit and HHO kit to the 100cc 2-stroke engine which gives better mileage and low emissions from the engine.

5.2.3 LPG INLET AND REGULATOR



FIG 5.6 LPG INLET AND REGULATOR

From the above image, we can see that both the LPG inlet and LPG regulator to the modified bike LPG regulator play a major role in LPG bike controlling the LPG pressure and flow rate to the engine.

5.3 COMPUTERISED POLLUTION TESTING REPORTS

computerized pollution testing of gasoline-powered automobiles may be tested using a contemporary, effective approach. The findings of the computerized testing are precise and trustworthy, making it simpler for the government to enact pollution control laws and for car owners to make sure their cars adhere to environmental requirements. Additionally, the use of computerized testing has lessened the possibility of human mistakes and the requirement for manual record-keeping, increasing the testing process' overall efficiency and accuracy. Graham, L. A (2008)

5.3.1 POLLUTION REPORT FOR PETROL

COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No. **55739** Rule 115(2) Of C.M.V.Rules 1989 **All India Valid**

AUTHORISED by Transport Department, Govt. of A.P.

Type of Vehicle: 2 Wheelers Fuel: **PETROL/LPG/CNG**
 Type of Engine: 4 Stroke Catalyst : No
 Make: HERO Date: 19 Mar 2023
 Model: PASSION PRO Time: 11:27:24

0001728

PTS Licence No.: TN14B4482
 Vehicle Registration.No.: Mar 2016
 Year of Registration : 2 and 3 Wheelers
 Odometer Reading: (4 Stroke)
 Mrf after 31/3/2000

Test Result:

Regulation (%)	Actual Reading	% Vol:
CO	3.5	2.85
HC	4500	1425
CO ₂		

Certified that this Vehicle's CO Emission level confirms to the Standards prescribed under Rule 115(2) of CMV Rules 1989

Validity: 6 Months

Sri Vani Mobile Pollution Test Center Seal of Test station: SHIVA REDDY Authorised Signature: Valid Upto: 18 Sep 2023

Photograph of the Vehicle

Pollution Testing Stations Association Andhra Pradesh

FIG 5.7 POLLUTION REPORT FOR PETROL,

The above Fig 5.7 shows the computerized pollution report on the bike which runs on the petrol

5.3.2 POLLUTION REPORT FOR PETROL+HYDROGEN

COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No. **55741** Rule 115(2) Of C.M.V.Rules 1989 **All India Valid**

AUTHORISED by Transport Department, Govt. of A.P.

Type of Vehicle: 2 Stroke Fuel: **PETROL/H2/CNG**
 Type of Engine: 4 Stroke Catalyst : No
 Make: PASSION PRO Date: 19 Mar 2023
 Model: Time: 11:36:02

0001730

PTS Licence No.: TN14B4482
 Vehicle Registration.No.: Apr 2016
 Year of Registration : 2 and 3 Wheelers
 Odometer Reading: (2 Stroke) Only
 Mrf after 31/3/2000

Test Result:

Regulation (%)	Actual Reading	% Vol:
CO	3.5	2.51
HC	6000	920
CO ₂		

Certified that this Vehicle's CO Emission level confirms to the Standards prescribed under Rule 115(2) of CMV Rules 1989

Validity: 6 Months

Sri Vani Mobile Pollution Test Center Seal of Test station: SHIVA REDDY Authorised Signature: Valid Upto: 18 Sep 2023

Photograph of the Vehicle

Pollution Testing Stations Association Andhra Pradesh

FIG 5.8 POLLUTION REPORT FOR PETROL+HYDROGEN

The above report shows the pollution report on the bike when runs on a combination of petrol and hydrogen in this report we can observe the low emission when the bike runs on the combination of petrol and hydrogen as compared, to a bike that runs on only petrol. Tollefson, J. (2010)

5.3.3 POLLUTION REPORT FOR LPG

COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE
Serial No. 55740
Rule 115(2) Of C.M.V.Rules 1989
All India Valid

AUTHORISED by Transport Department, Govt. of A.P.

Type of Vehicle: 2 Wheeler
Type of Engine: 2 Stroke
Make: HERO
Model: PASSION PRO
Fuel: PETROL/LPG/CNG
Catalyst : No
Date: 19 Mar 2023
Time: 11:31:51

PTS Licence No.: 0001729
Vehicle Registration.No.: TN14B4482
Year of Registration : Mar 2016
Odometer Reading: 2 and 3 Wheelers (2 Stroke) Only
Mrf after 31/3/2000

Test Result:

Regulation (%)	Actual Reading	% Vol:
CO 3.5	2.0	PPM
HC 6000	% O ₂ 1100	%

Certified that this Vehicle's CO Emission level confirms to the Standards prescribed under Rule 115(2) of CMV Rules 1989

Sri Vani Mobile Testing Station
Seal of Test station: _____
Authorized Signature: _____
Valid Upto: 18 Sep 2023
Validity: 6 Months

PREVENT POLLUTION PROTECT ENVIRONMENT. (PTSA - A.P.)

Pollution Testing Stations Association Andhra Pradesh

FIG 5.9 POLLUTION REPORT FOR LPG

The above pollution report on the bike which runs on the LPG, as compared to the petrol, LPG is low in emission.

5.3.4 POLLUTION REPORT FOR LPG+HYDROGEN

COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE
Serial No. 55742
Rule 115(2) Of C.M.V.Rules 1989
All India Valid

AUTHORISED by Transport Department, Govt. of A.P.

Type of Vehicle: 2 Wheeler
Type of Engine: 2 Stroke
Make: HERO
Model: PASSION PRO
Fuel: PETROL/LPG/CNG
Catalyst : No
Date: 19 Mar 2023
Time: 11:38:17

PTS Licence No.: 0001731
Vehicle Registration.No.: TN14B4482
Year of Registration : Apr 2016
Odometer Reading: 2 and 3 Wheelers (2 Stroke) Only
Mrf after 31/3/2000

Test Result:

Regulation (%)	Actual Reading	% Vol:
CO 3.5	1.9	PPM
HC 6000	% O ₂ 890	%

Certified that this Vehicle's CO Emission level confirms to the Standards prescribed under Rule 115(2) of CMV Rules 1989

Sri Vani Mobile Testing Center
Seal of Test station: _____
Authorized Signature: _____
Valid Upto: 18 Sep 2023
Validity: 6 Months

PREVENT POLLUTION PROTECT ENVIRONMENT. (PTSA - A.P.)

Pollution Testing Stations Association Andhra Pradesh

FIG 5.10 POLLUTION REPORT FOR LPG + HYDROGEN

The above pollution report for the bike runs on both LPG and hydrogen. In this report, we can observe that it is very low in emission when compared to other combinations or only in LPG also Akal, D., (2020)

5.4 EMISSION RESULTS

We have tested the bike with the combinations of petrol, petrol+hydrogen, and LPG, LPG+hydrogen, The emission results are shown as below.

5.4.1 EMISSIONS OF CARBON MONOXIDE

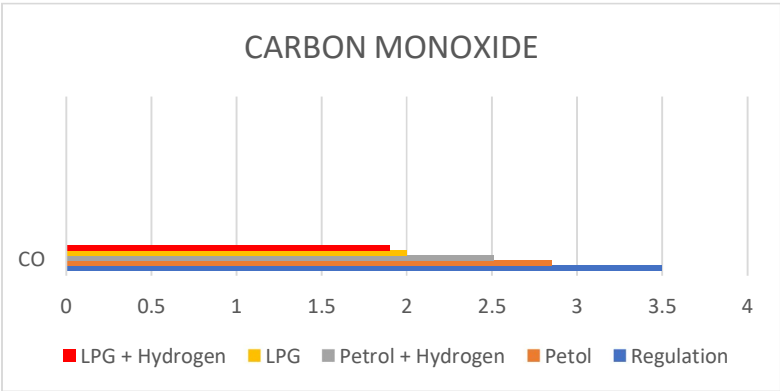


FIG 5.11 EMISSION OF CARBON MONOXIDE

From the above graph, we can see the emission values for carbon monoxide as per the actual regulations

5.4.2 EMISSION OF HYDROCARBON

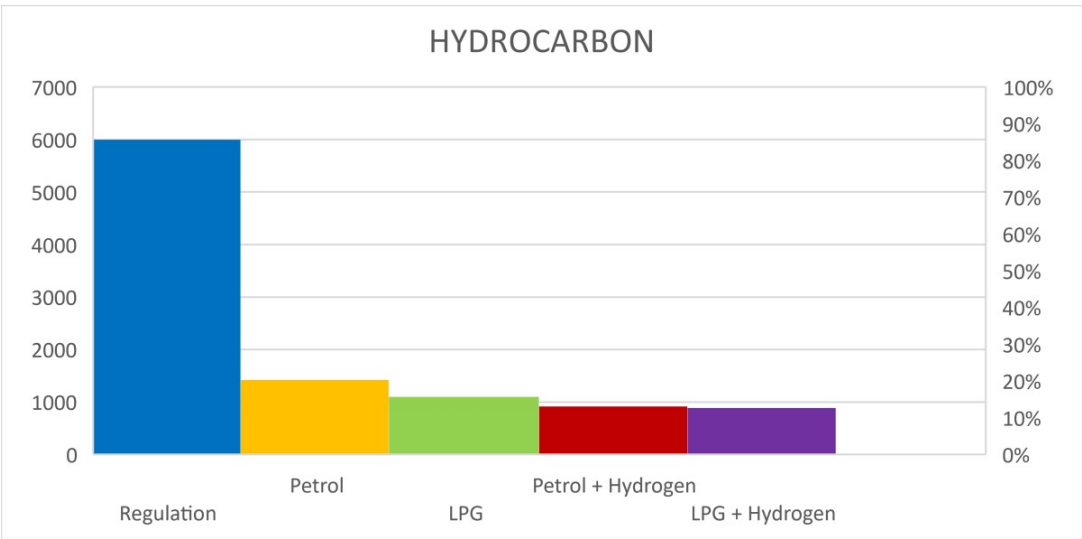


FIG 5.12 EMISSION OF HYDRO CARBON

From the above hydrocarbon emission values. we can notice very low values when bikes run with hydrogen and compared to both fuels LPG is very less in pollution than petrol.

5.5 EMISSION TESTING VALUES

The outcomes of emission values of the Dual fuel bike are shown as below

TABLE 5.1 EMISSION VALUES

Pollutants	Press STD	Actual reading of Petrol	Actual reading of Petrol + Hydrogen	Actual reading of LPG	Actual reading of LPG + Hydrogen
CO	3.5	2.85	2.51	2.0	1.9
HC	6000	1425	920	1100	890

It is understood that the two-stroke SI engine fuel bike passes the transport department's pollution testing using fuels like petrol in combination with hydrogen and LPG combined with hydrogen. It has been shown that by reducing emissions and using less fuel, we can ride bikes without harming the environment even while using fuels like LPG and hydrogen. Bielaczyc, (2011)

CHAPTER 6

SUMMARY AND CONCLUSION

A two-stroke LPG hydrogen engine that combines LPG and hydrogen as fuel would be a technologically advanced, socioeconomically viable, and environmentally beneficial internal combustion engine. This engine would be more effective than a four-stroke engine and release fewer pollutants and greenhouse gases, among other advantages. Low pollution in the bike is possible by using the electrolysis kit and LPG kit and also not only the pollution is decreased the fuel efficiency and engine running will be very well improved with these modifications in the modified bike.

The creation of such an engine may be a step towards a transportation sector that is more environmentally friendly and sustainable. The adoption of cleaner-burning fuels and more efficient engines may help reduce carbon emissions and lessen the environmental effect of transportation in light of growing concerns about climate change and environmental pollution. Even if there are difficulties to be solved, further study and development of this technology might offer major economic and environmental advantages.

References

- [1] Ashok, B., Kumar, A. N., Jacob, A., & Vignesh, R. (2022). Emission formation in IC engines. In *NOx Emission Control Technologies in Stationary and Automotive Internal Combustion Engines* (pp. 1-38). Elsevier.
- [2] Awad, Omar I., R. Mamat, Thamir K. Ibrahim, Ali Thaeer Hammid, I. M. Yusri, Mohd Adnin Hamidi, Ali M. Humada, and A. F. Yusop. "Overview of the oxygenated fuels in spark ignition engine: Environmental and performance." *Renewable and Sustainable Energy Reviews* 91 (2018): 394-408.
- [3] Aydin, Kadir, and Raif Kenanoğlu. "Effects of hydrogenation of fossil fuels with hydrogen and hydroxy gas on performance and emissions of internal combustion engines." *International Journal of Hydrogen Energy* 43, no. 30 (2018): 14047-14058.
- [4] Bayraktar, H., & Durgun, O. (2005). Investigating the effects of LPG on spark ignition engine combustion and performance. *Energy conversion and management*, 46(13-14), 2317-2333.
- [5] Bielaczyc, P., Szczotka, A., Pajdowski, P., & Woodburn, J. (2011). Development of vehicle exhaust emission testing methods-BOSMAL's new emission testing laboratory. *Silniki Spalinowe*, 50, 3-12.
- [6] Ceviz, M. A., Kaleli, A., & Güner, E. (2015). Controlling LPG temperature for SI engine applications. *Applied Thermal Engineering*, 82, 298-305.
- [7] Ceviz, M. A., & Kaleli, A. (2015, October). Pressure Regulator Optimization in LPG Fuel Injection Systems. In *2015 International Conference on Sustainable Energy and Environmental Engineering* (pp. 62-64). Atlantis Press.
- [8] Dincer, Ibrahim; Acar, Canan (2015). A review on clean energy solutions for better sustainability. *International Journal of Energy Research*, 39(5), 585–606. doi:10.1002/er.3329
- [9] Dahake, M. R., S. D. Patil, and S. E. Patil. "Effect of hydroxy gas addition on performance and emissions of diesel engine." *Int. Res. J. Eng. Technol* 3, no. 01 (2016).
- [10] Fil, H. E., & Akansu, S. O. (2022). The impact of modified injection timing methods on performance, combustion and pollution emissions in CI engine using diesel-gasoline mixtures. *Fuel*, 328, 125268.
- [11] Jones, Aled W. (2015). Perceived barriers and policy solutions in clean energy infrastructure investment. *Journal of Cleaner Production*, 104(), 297–304. doi:10.1016/j.jclepro.2015.05.072
- [12] José Goldemberg (2006). The promise of clean energy. , 34(15), 2185–2190. doi:10.1016/j.enpol.2005.03.009

- [13] Kim, C. K., Lee, I. K., & Cho, S. H. (2011). Study for Failure Examples of Solenoid Valve, Relay and Idle Speed Control Actuator in Liquid Petroleum Gas vehicle Engines. *Journal of the Korean Institute of Gas*, 15(3), 47-52.
- [14] Karamangil, M. I. (2007). Development of the auto gas and LPG-powered vehicle sector in Turkey: A statistical case study of the sector for Bursa. *Energy policy*, 35(1), 640-649
- [15] Kim, Young-Min, et al. "Potential and evolution of compressed air energy storage: energy and exergy analyses." *Entropy* 14.8 (2012): 1501-1521.
- [16] Lowitzsch, J.; Hoicka, C.E.; van Tulder, F.J. (2020). Renewable energy communities under the 2019 European Clean Energy Package â Governance model for the energy clusters of the future?. *Renewable and Sustainable Energy Reviews*, (), 109489â.
- [17] Mitrašinović, A. M. (2021). Photovoltaics advancements for transition from renewable to clean energy. *Energy*, 237, 121510.
- [18] N.L. Panwar; S.C. Kaushik; Surendra Kothari (2011). Role of renewable energy sources in environmental protection: A review. , 15(3), 1513â1524. doi:10.1016/j.rser.2010.11.037
- [19] Ravi, K., Mathew, S., Bhasker, J. P., & Porpatham, E. (2017). Gaseous alternative fuels for Spark Ignition Engines-A technical review. *Journal of Chemical and Pharmaceutical Sciences*, 10(1), 93-99.
- [20] Santram, B. S., Salim, T. M. S., Saleem, S. M. S., & Mujeebullah, A. S. A. (2015). Dual fuel bike (LPG cum petrol). *International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME)*, 2.
- [21] Sudhakaran, D. R., Aravinthkumar, G., Naveenkumar, M., Veerakumar, S., & Vigneshvar, M. (2014). Enhancing The Ic Engine Performance By Using The Electrolysis And Preheating Process. *IOSR Journal Of Computer Engineering (IOSR-JCE)*.
- [22] Setiyo, M., & Waluyo, B. (2019). Mixer with secondary venturi: an invention for the first-generation LPG kits. *International Journal of Automotive Science and Technology*, 3(1), 21-26.
- [23] Setyono, G. (2020). Hydroxy gas (HHO) supplement of ethanol fuel mixture in a single-cylinder spark-ignition matic-engine. *Jurnal Teknik Mesin dan Mekatronika (Journal of Mechanical Engineering and Mechatronics)*, 5(2), 114-121.
- [24] Sher, E. (1998). *Handbook of air pollution from internal combustion engines: pollutant formation and control*. Academic Press.
- [25] Shadidi, B., Najafi, G., & Yusaf, T. (2021). A review of hydrogen as a fuel in internal combustion engines. *Energies*, 14(19), 6209.

- [26] Stern, Alvin G. (2018). A new sustainable hydrogen clean energy paradigm. International Journal of Hydrogen Energy, (), S0360319917349029–. doi:10.1016/j.ijhydene.2017.12.180
- [27] Stoyanov, S. N., Mihaylov, V., Ivanov, Z., & Radev, R. (2021). System for studying the parameters of gas solenoid valves. ANNUAL JOURNAL OF TECHNICAL UNIVERSITY OF VARNA, BULGARIA, 5(2), 112-121.
- [28] Tüccar, G. (2018). Effect of hydroxy gas enrichment on vibration, noise and combustion characteristics of a diesel engine fueled with Foeniculum vulgare oil biodiesel and diesel fuel. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 40(10), 1257-1265.
- [29] Tollefson, J. (2010). Hydrogen vehicles: fuel of the future. Nature, 464(7293), 1262-1264.
- [30] Yilmaz, A. C., Uludamar, E., & Aydin, K. (2010). Effect of hydroxy (HHO) gas addition on performance and exhaust emissions in compression ignition engines. international journal of hydrogen energy, 35(20), 11366-11372.