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An Innovative Hydrogen Dual Fuel Engine with Integrated Aqua Silencer

Sivakumar Karthikeyan[1], Mithunn Balaji[2]

[1]Department of Mechanical Engineering, SRM Valliammai Engineering College, Anna University,
Chennai, 603203, India

[2]Amador Valley High School, Pleasanton, California, 94588, USA

Abstract

Hydrogen fuel enhancement is the process of using a mixture of hydrogen and conventional hydrocarbon fuel in an internal combustion engine, typically in a car or truck, to improve fuel economy, power output, or both. Methods include hydrogen produced through electrolysis, storing hydrogen on a vehicle as a secondary fuel, or reforming conventional fuel into hydrogen. An aqua silencer is an attempt in this direction; it mainly deals with controlling emissions and noise. An aqua silencer has to be attached to the engine exhaust. The sound produced under water is less hearable than in the atmosphere. This is mainly because of small sprockets in water molecules, which lower its amplitude thus, lowers the sound level because of this property water is used in silencers and its name is AQUA SILENCER. The noise and smoke levels are considerably less than the conventional silencer, it is cheaper, does not need a catalytic converter, and is easy to install.

Keywords: **Two-wheeler engine; Hydrogen storage cylinder; Regulator and air filter**

I. INTRODUCTION

A. *Hydrogen petrol fuel mixture*

The use of hydrogen (H2) as a fuel in internal combustion engines has been studied by several research groups worldwide in response to the consumer demand for more environmentally friendly fuel chains. Compared with conventional, fossil hydrocarbon fuels, hydrogen offers practically an elimination of pollutants such as carbon monoxide and unburnt hydrocarbons, known to pose health risks in densely populated areas. The only nontrivial pollutant from hydrogen engines is nitrogen oxides (NOx), however, the characteristics of hydrogen fuel, such as a high flame speed and extensive lean burn operation possibilities, allow significant reductions in NOx compared to when using conventional fuels. The incentives for a hydrogen economy are the emissions, the potentially CO2-free use, the sustainability, and the energy security.

In this project the focus is on the use of hydrogen in internal combustion engines (ICE), or more precisely, hydrogen-fueled spark ignition (SI) engines. Internal combustion engines are classified as spark ignition (SI) and compression ignition (CI) engines, depending on the combustion process initiated in the cylinder. A spark plug initiates the combustion of the fuel-air mixture in SI engines. In CI engines, the fuel-air mixture is self-ignited by compression. It must be mentioned that hydrogen's auto-ignition temperature is high (about 576), and it is impossible to bring hydrogen to its auto-ignition temperature by compression only. So, Supportive ignition triggering devices should be used in the combustion chamber. The current energy crisis urges us to explore a variety of alternate methods to satisfy the world's energy demands. A major market solution for the energy crisis is increasing supply and reducing demand for crude oil. Increasing the list of feasible fuel alternatives reduces the demand for crude oil. Among all the potential environment-friendly alternative fuels of the future, hydrogen is one of the most promising in terms of practicality, long-term feasibility and low pollution levels.

Hydrogen-fueled engines are known for many advantages, among which the very low concentration of pollutants in the exhaust gases compared to internal combustion engines using traditional or other alternative fuels. Further on, because of the wide flammability limits and the high flame propagation speed of hydrogen, a hydrogen-fueled engine is capable of very lean combustion. To be able to run a hydrogen engine, the mixture formation of air and hydrogen does not need precise control. Consequently, simple systems such as an external mixture system with a gas carburetor (venture type) can be used for the fuel supply.

The current energy crisis urges us to explore a variety of alternate methods to satisfy the world's energy demands. A major market solution for the energy crisis is increasing supply and reducing demand for crude oil. By increasing the list of feasible fuel alternatives, the demand for crude oil is reduced. Among all the potential environment-friendly alternative fuels of the future, hydrogen is one of the most promising in terms of practicality, long-term feasibility and low pollution levels. Thus, it can contribute majorly towards solving two major issues: energy security and climate change.

Hydrogen has a very low energy density when compared to gasoline. This is a disadvantage for storage, transport and safety purposes since it will need to be stored at very high pressures. In addition, hydrogen cannot be used to produce energy by combustion at temperatures below 0 Celsius, since the fuel requires a higher temperature to burn. Therefore, the challenge becomes storing hydrogen at extremely high pressures without drastically reducing the temperature.

B. *Alternative fuels*

Liquid fuels have over the past 100 years evolved as the fuels of choice for transport because of their high energy density and the ease of transport, storage and handling. Conventional fuels are complex mixtures that typically contain more than a hundred chemical components whose composition has changed and evolved over time and in connection to engine development. The development has been done in correlation with and to meet the engine development demand on power, efficiency and drivability. Over the last decades, ever more stringent emissions legislation has been added to the demands on the fuel and engine combination. When discussing alternatives to current fossil-based fuels for propulsion and power generation fuel properties are important criteria from a combustion point of view to take into consideration, since the combustion behavior relates to the main purpose of the heat machine, i.e., to convert chemical power to mechanical power.

However, the fuel in an internal combustion engine undergoes other processes and passes many systems before it is burned, as exemplified in Figure 1, and these also have to be considered. All the systems will influence the fuel and the fuel's different properties will influence the systems. Fuel is filled and stored in a tank of some type. The fuel will interact with materials and impurities in both storage tank and fuel system. The fuel will also be exposed to various ambient conditions such as temperature, moisture and exposure to oxygen in air. Examples of dependence are vapour pressure, connected to high and low temperatures, deposits depending on low-temperature solubility and oxidation stability depending on oxygen content and contact. From the storage, fuel is pumped into the fuel system with feed pumps and pressure pumps, depending on the type of fuel and fuel system. This line also includes a various number of filtering stages.

All these systems will influence and interact with the fuel when facing material interactions which typically could cause deposits and gum formation. Vapour pressure is also important from a pumping and gas phase formation point of view. Filters are inserted in the line to prevent even very small particles from entering the injectors, but the filters are then very sensitive to clogging due to gum formation or phase separation of components. Finally, fuel enters the injectors where the energy provided by the pressure level is converted into velocity to inject the demanded amount of fuel and, in the case of liquid fuels, to provide energy for spray formation and breakup. The injectors contain small passages and nozzles and also include moving parts which are all very sensitive to clogging and material detoration. The influence and importance of the fuel’s physical and chemical properties in addition to its combustion characteristics are as indicated above covering the whole fuel supply chain from source to end use. The two main renewable alternative fuels widely used for transportation are ethanol, and biodiesel (FAME and HVO). Cellulosic and algal renewable fuels will need to emerge with sufficient economic advantage to accelerate alternative fuel usage, and in a manner that better addresses fuel distribution and storage. One way to address the latter is to produce alternative feedstocks that are composed of fully hydrogenated species similar to those found in petroleum-derived fuels. Upgrading will require additional hydrogen, and methods for generating hydrogen without increasing carbon emissions are critical needs for the future.

C. *Conventional fuel requirements*

Fossil fuels are formed by natural resources such as anaerobic decomposition of buried dead organisms. The age of the organisms and their resulting fossil fuels is typically millions of years and sometimes exceeds 650 million years. The fossil fuels include coal, petroleum, and natural gas which contain high percentages of carbon. Fossil fuels range from volatile materials with low carbon: hydrogen ratios like methane, liquid petroleum and nonvolatile materials composed of almost pure carbon like anthracite coal. Methane can be found in hydrocarbon fields alone, associated with oil, or in the form of methane catharses. It is generally accepted that they formed from the fossilized remains of dead plants and animals by exposure to heat and pressure in the Earth's crust over millions of years.

D. *Literature review*

Hydrogen Petrol Mixture SI Engine Energy stored in hydrogen would be available at any time and any place on Earth, regardless of when or where the solar irradiance, hydropower, or other renewable sources such as biomass, ocean energy, or wind energy was converted [1-5], The combustion of fossil fuels has caused serious problems to the environment and the geopolitical climate of the world. Hydrogen is a fuel with a heat content nearly three times that of gasoline. From our work, we experimented and found out that the efficiency of an IC engine can be rapidly increased by mixing hydrogen with gasoline.

The optimized mixture formation for hydrogen-fueled engines’ both intake port injection type and in-cylinder injection type hydrogen fuel supply system is designed for a single-cylinder research engine to investigate the effect of mixture formation on the performance of the hydrogen-fueled engine [6-11]. The intake port injection is superior in thermal efficiency and engine operation stability at low load conditions. However, the in-cylinder injection is superior for high load conditions. In an engine experience with throttling conditions, the engine with intake port injection operates more stable and efficiently when fuel- Air equivalence ratio is maintained above a certain level despite the pumping loss due to stable combustion. Thus, the hydrogen-fueled engine can be operated more stably with the in-cylinder injection at high load and more efficiently with the intake port injection at low load.

Therefore, the optimized operation of the hydrogen-fueled engine can be achieved with a dual injection system and throttle valve control.

Combustion characteristics of intake port injection type hydrogen-fueled engine, this paper describes the experimental results on a hydrogen-fueledsingle-cylinder engine to study of characteristics solenoid-driven intake port injection type hydrogen injection valve [12-20]. In experiments, the fuel-air equivalence ratio was varied from the lean limit at which stable operation was guaranteed to the rich limit at which flash-back occurred, and spark timing was also changed. As a consequence, a hydrogen intake port injection system can be easily installed on a spark ignition engine only with simple modification and the flow rate of hydrogen supplied can also be controlled conveniently. In this case, the most serious problem is flash-back and it can be suppressed by accurate control of injection timing and elimination of hot spots on the surface of the combustion chamber.

The review of the effect of hydrogen addition on the performance and emission of the compression-ignition engine' Diesel engine produce high emission of smoke, particulate matter and nitrogen oxide [21-26]. The challenge now is the decrease exhaust emissions without making any major changes to their mechanical configuration. Therefore, adding hydrogen becomes a natural choice to enhance the performance and emission of diesel engines. This paper offers an overview of the effect of hydrogen in addition to the diesel engine.

The overall findings from the review suggest that the air-fuel ratio, engine speed, and engine load play a key role in the performance and emission of diesel engines with hydrogen enrichment. The brake thermal efficiency (BTE), brake power output, brake mean effective pressure (BMEP) and specific energy consumption (SEC)are dependent on the operating condition of the engine when adding the hydrogen. It is also found that increasing the percentage of hydrogen will affect emission, so the reduction in unburned hydrocarbon (HC)carbon monoxide (CO), carbon dioxide (CO2), particular matter (PM), and smoke are observed when adding the hydrogen. However, nitrogen Oxide (NOx)is increased when enriching H2, but this increase in NOx can be controlled by numerous injections, exhaust gas recirculation (EGR), or water injection as well as exhaust after-treatment has been discussed in this paper.

Numerical simulation of the flow field of used pneumatic silencer [27-30]. The outflow velocity distribution and inner pressure distribution could be improved by improving the structure of the silencer. Therefore, modifying inner area suction or reducing the area of the shell & end cover. A case study on the compatibility of automotive exhaust thermoelectric generation systems, catalytic converters and muffler research was carried out. To test three cases about the installation position of the thermoelectric generator. Various cases were tested and, in this paper, case 2 is the best position for installation [31]&[32].

II. ILLUSTRATIONS

A. Aqua silencer

Air pollution is a major problem. The main pollutants contributed by automobiles are (CO), Un-burnt Hydro Carbon (UBHC), (NOx) and lead, etc. Other sources which cause pollution are electric power generating stations and Industries. So, serious attempts must be made to conserve the earth's environment from degradation. An aqua silencer is an attempt in this direction. It mainly deals with the control of emissions and noise. An aqua silencer is fitted to the exhaust pipe of an engine as shown in Fig. 1. Air pollution is the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms or damage the natural environment. These substances called pollutants can occur naturally or they can be produced by human activities. Natural pollutants include dust, pollen, salt particles, smoke from forest fires, and gases from organic waste. Most pollution caused by human activities is directly or indirectly the result of burning of fuels in furnaces or engines.

The plastic container containing distilled water and stainless-steel plates which are connected to the battery, gives out bubble formation which is very quick and uniform. The bubble formation on connection to the battery is very quick and this hydrogen gas which is produced at a rate of 1 bubble per second can be easily put inside the engine.

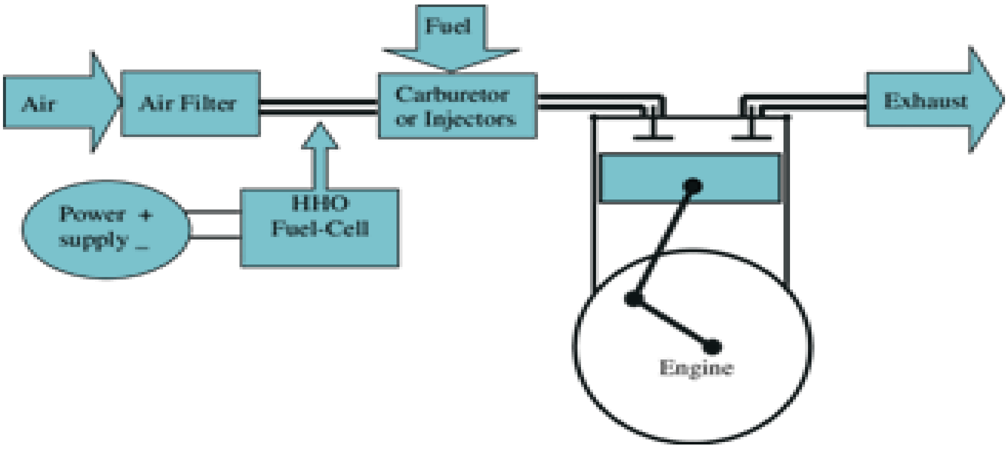


Fig. 1 Line diagram of an engine with an aqua silencer

The combustion of hydrogen with oxygen produces water as its only product:

$$2H_2 + O_2 \rightarrow 2H_2O \qquad (1)$$

The exhaust of the engine has also very little nitrous oxide content and carbon dioxide content. For hydrocarbon engines, lean operation also leads to lower emissions of carbon monoxide and unburned hydrocarbons. As more oxygen is available than required to combust the fuel, the excess oxygen oxidizes more carbon monoxide into carbon dioxide, a less harmful emission.

The excess oxygen also helps to complete the combustion, decreasing the number of unburned hydrocarbons. In contrast, the combustion of high-temperature combustion fuels, such as kerosene, gasoline, or natural gas, with air can produce oxides of nitrogen, known as NOx. Tuning a hydrogen engine in 1976 to produce the greatest number of emissions possible resulted in emissions comparable with consumer-operated gasoline engines from 1976.

$$H_2 + O_2 + N_2 \rightarrow H_2O + NO_x \qquad (2)$$

B.Hydrogen preparation

Hydrogen is an energy carrier, not an energy source— hydrogen stores and delivers energy in a usable form, but it must be produced from hydrogen-containing compounds. Hydrogen can be produced using diverse, domestic resources including fossil fuels, such as natural gas and coal (preferentially with carbon capture, utilization, and storage); biomass grown from renewable, non-food crops; or using nuclear energy and renewable energy sources, such as wind, solar, geothermal, and hydroelectric power to split water. This diversity of potential supply sources is an important reason why hydrogen is such a promising energy carrier. Hydrogen can be produced at large central plants, at medium-scale semi-central plants, or in small distributed units located at or very near the point of use, such as at refueling stations or stationary power sites. Researchers are developing a wide range of technologies to produce hydrogen economically from a variety of resources in environmentally friendly ways.

C. Natural gas reforming

Hydrogen can be produced from natural gas using high-temperature steam. This process, called steam methane reforming, accounts for about 95% of the hydrogen used today in the U.S. Another method, called partial oxidation, produces hydrogen by burning methane in the air. Both steam reforming and partial oxidation produce a “synthesis gas” or “syngas,” which is then reacted with additional steam to produce a higher hydrogen content gas stream.

D. Renewable electrolysis

Electrolysis uses an electric current to split water into hydrogen and oxygen. The electricity required can be generated using any of several resources. However, to minimize greenhouse gas emissions, electricity generation using renewable energy technologies (such as wind, solar, geothermal, and hydroelectric power), nuclear energy, or natural gas and coal with carbon capture, utilization, and storage are preferred.

E. Gasification

Gasification is a process in which coal or biomass is converted into gaseous components by applying heat under pressure and in the presence of air/oxygen and steam. A subsequent series of chemical reactions produce syngas, which are then reacted with steam to produce a gas stream with an increased hydrogen concentration that then can be separated and purified. With carbon capture and storage, hydrogen can be produced directly from coal with near-zero greenhouse gas emissions. Since growing biomass consumes carbon dioxide from the atmosphere, producing hydrogen through biomass gasification results in near-zero net greenhouse gas emissions.

F. Renewable liquid reforming

Biomass can also be processed to make renewable liquid fuels, such as ethanol or bio-oil, which are relatively convenient to transport and can be reacted with high-temperature steam to produce hydrogen at or near the point of use. Researchers are also exploring a variation of this technology known as aqueous-phase reforming.

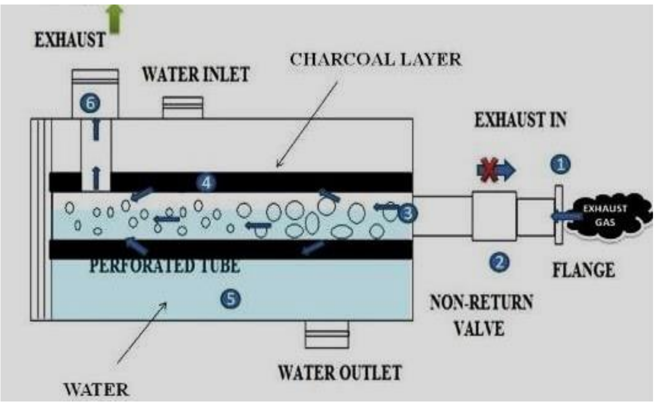


Fig. 2 Aqua Silencer

G. Nuclear high-temperature electrolysis

Heat from a nuclear reactor can be used to improve the efficiency of water electrolysis to produce hydrogen. By increasing the temperature of the water, less electricity is required to split it into hydrogen and oxygen, which reduces the total energy required.

H. High-temperature thermochemical water-splitting

Another water-splitting method uses high temperatures generated by solar concentrators (mirrors that focus and intensify sunlight) or nuclear reactors to drive a series of chemical reactions to split water into hydrogen and oxygen. All of the intermediate process chemicals are recycled within the process.

I. Biological

Certain microbes, such as green algae and cyan bacteria, produce hydrogen by splitting water in the presence of sunlight as a byproduct of their natural metabolic processes. Other microbes can extract hydrogen directly from biomass.

III. PHOTOELECTROCHEMICAL (PEC)

Hydrogen can be produced directly from water using sunlight and a special class of semiconductor materials. These highly specialized semiconductors absorb sunlight and use the light energy to directly split water molecules into hydrogen and oxygen. An Aqua silencer is an updated version of a normal silencer as shown in Fig. 2. As the exhaust gases enter into the aqua silencer, the perforated tube converts high-mass bubbles into low-mass bubbles after they come into contact with lime water, they chemically react with it and pass through the charcoal layer which again purify the gases. The gases like HC and CO are absorbed from the emission. The charcoal is highly porous and possesses extra free valences so it has high absorption capacity. The purified gases are then released into the atmosphere. The contaminated lime water which has precipitates of calcium carbonate and bicarbonates in the aqua silencer is replaced once a year. The charcoal layer is covered with an outer shell that is filled with water. The sound produced under water is less hearable than the sound produced in the atmosphere. This is mainly because of small sprockets in water molecules, which lowers its amplitude thus, lowers the sound level hence aqua silencer reduces noise and pollution.

IV. DUAL FUEL ENGINE COMPONENTS

A. *Regulator*

Shutoff valves that come with gas cylinders cannot be used to control the discharge rate of gas in use. Additional equipment that is required for hydrogen gas delivery systems includes regulators with pressure gauges. As with valves and piping materials, these instruments must be intended for use with hydrogen gas.

B. *Hydrogen gas cylinders*

The following are some safe handling guidelines that have been established by the Compressed Gas Association for single hydrogen gas cylinders. By following these guidelines, you can assure the safety of your hydrogen gas operations.

C. *Connecting tubes*

When moving hydrogen, the following general precautions should be taken. Replace the cylinder valve cap before moving hydrogen from its secured, in-use position. Move hydrogen to cylinder carts or with other approved cylinder transferring devices. Never roll or drop cylinders. Severe foot injuries are damage to the cylinder could result.

D. *Hydrogen gas storing cylinders*

The following points are important to follow for storing hydrogen gas cylinders that are awaiting removal or anticipated for use. hydrogen gas cylinders should be stored outside. Indoor storage of hydrogen requires specially designed facilities. Consult the industrial hygiene and safety group (ESI-5) and the facility risk management group (ESH-3) before setting up indoor storage locations for hydrogen cylinders and not in use.

V. HYDROGEN ENGINE SPECIFICATION

A. Engine

The engine shall utilize hydrogen fuel injection with the injector locator to inject fuel either by throttle body or intake port directly into the cylinder. For conversion of vehicles not originally manufactured by the HICE, vehicle supplier, OEM engine modification shall not require body modification, with either intruding upon interior passenger space or reduce over hood visibility on vehicles.

B. *Durability*

The vehicle shall be capable of completing the HICEV America rough road test (ETA-HITO-005) INCLUDING (1) driving through standing water without damage, and (2) standing for an extended period in extreme temperature without damage or failure of the vehicle of the system. The vehicle should be capable of completing the HEV America rough road test (ETA-HITP-005) without becoming inoperable. Vehicles shall be capable of completing all HICEV America tests without repair exceeding a simulative total of 72 hours. The vehicle should be capable of standing for extended periods in extreme temperatures without damage or failure of the vehicle in the system.

C. *Fuel economy*

Vehicles should be accompanied by fuel economy data from suppliers testing Vehicles will be tested for fuel economy while operating on a combined drive cycle test consisting of two (2) Urban dynamometer driving schedules (UDDS) followed by two highway fuel economy driving schedules.

D. Engine design specification

Displacement -105.6cc
Fuel type -dual fuel (petrol hydrogen)
Stroke -four-stroke petrol engine
Type -air-cooled
No. of cylinder -single cylinder
Maximum power -7.6ps@7500rpm
Maximum torque -7.8nm@6000rpm
Water
Thermal properties water
Maximum density -1000kg/m3
Specific weight -9.807Kn/m3
Freezing point -0ºC
Boling point -100ºC
Latent heat of melting -334KJ/KG
Latent heat of evaporation -2270 KJ/kg
Specific heat -40187 KJ/Kg-K
Thermal expansion -4 C to 100 ºC

VI. EXISTING MODEL

The difference between a hydrogen IC Engine and a traditional gasoline engine could include hardened valves, valve seats, stronger connecting rods, non-platinum tipped spark plugs, higher voltage ignition coil, fuel injection for a designed gas instead of a liquid, larger crankshaft damper, stronger head gasket material, modified (for supercharge) intake manifold. positive pressure supercharges, and a high-temperature engine oil. All modifications would amount to about one point five times [1.5] the cost of a gasoline engine. These hydrogen engines burn fuel in the same manner that gasoline engines do. The power output of a direct-injected hydrogen engine vehicle is 20% more than in a gasoline engine vehicle and 42% more than a hydrogen engine vehicle using a carburetor. Hydrogen internal combustion engine cars are different from hydrogen fuel cell cars. The hydrogen internal combustion car is a slightly modified version of the traditional gasoline internal combustion engine car. These hydrogen engines burns fuel in the same manner that gasoline engine does.

VII. METHOD TO CONTROL WATER POLLUTION

A. Lime water wash method

The water is treated with the calculated quantity of slaked lime. After mixing the heavy precipitates settle down as sludge at the bottom of the tank is removed from time to time. Lime can neutralize any acid present in the water, and SO2 gases are removed from the flue gases forming calcium sulfate:

$$CO(g) + H_2O(l) \rightarrow CO_2(g) + H_2(g)\ 2HCL + Ca(OH)_2.\ CaCl_2 + 2H_2 \qquad (3)$$

$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O$ (4)

$Ca(OH)_2(a) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$ (5)

$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$ (colorless) (6)

B. Absorption process

Activated charcoal is available in granule powdered form. A soothingly porous and possesses free valances. So, possesses a high absorption capacity. Activated carbon is more widely used for the removal of waste from public water supplies. Because of its property of attracting gases, it finely divides solid particles and phenol-type impurities, The activated carbon usually in the powder form is added to the water either or before coagulation with sedimentation. The combustion of hydrogen with air can also produce oxides of nitrogen though in negligibly small amounts. Turning a hydrogen engine to create the most amounts of emission possible results in emissions compared with consumer-operated gasoline engines since 1976.

VIII. DESIGN CALCULATIONS

The Faraday Constant:

The Faraday constant is the most important information in electrolysis calculations. Make sure you understand the next bit.

Coulombs:

The Coulombs is a measure of the quantity of electricity. If a current of 1 ampere flows for 1 second then 1 coulomb of electricity has passed.

Calculation of hydrogen extraction:

The calculation of hydrogen extraction is based on the product of the electricity that has passed in a given time and the current in amps by the time in seconds.

NUMBER OF COULOMBS = CURRENT IN AMPS × TIME IN SECONDS

The volume of water used for electrolysis = 2litrs Electrode used in electrolysis = stainless steel G316 Battery used for electrolysis

= 2.5A, 12V DC supply to find flow of hydrogen Coulomb = 2.5 × 60 = 150 coulomb

$2 H^+(aq) + 2e^- \rightarrow H_2(g)$

Mole of Hydrogen = 1

A mole of electron Avogadro number = 6.02 x 1023.

One mole of electron carry = 6.02 x 1023 x 1.6 x 10-19

= 96320 Coulombs This value is known as the Faraday constant.

IX. RESULT AND DISCUSSION

The average readings are shown below table and graphs:

Table I not only showcases the average speed but also highlights additional performance metrics such as fuel efficiency, engine temperature, and emissions output for both petrol and dual fuel modes. These supplementary data provide a comprehensive understanding of the overall operational characteristics of each mode at different speeds.

Additionally, the comparison between petrol and dual-fuel modes extends beyond just speed, shedding light on the sustainability and cost-effectiveness of utilizing dual-fuel technology.

TABLE I: MODE OF OPERATION VS SPEED

Fuel /Speed limit	**30-40 (km/hr.)**	**50-60 (km/hr.)**	**80-90 (km/hr.)**
Petrol or Gasoline	68	76	35
Dual fuel mode	92	113	45

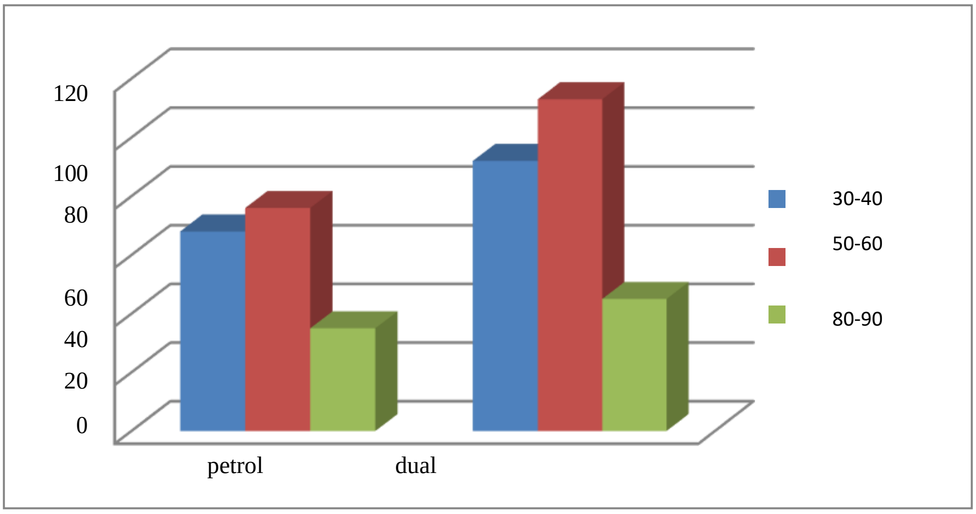


Fig.3, Petrol, dual fuel mode vs speed

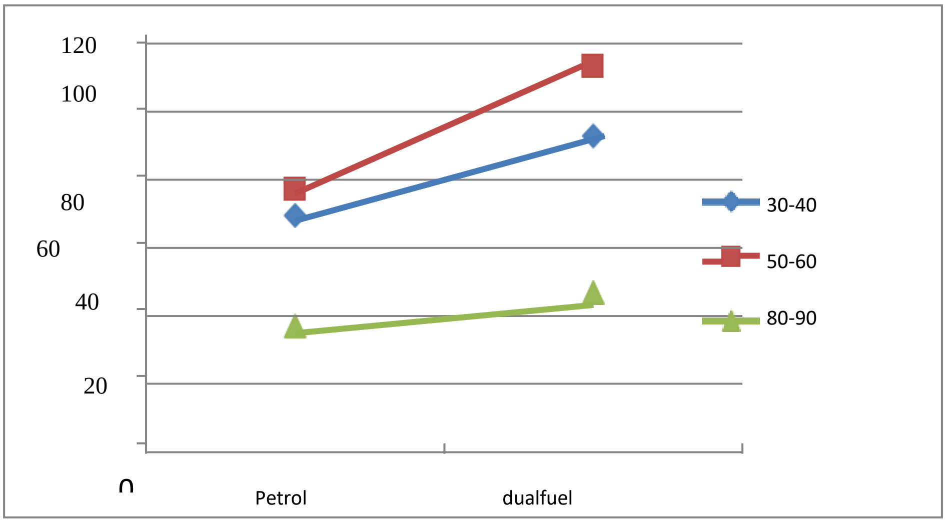


Fig.4, Mode of operation vs Speed

Figures 3 and 4 offer visual representations that aid in quickly grasping the performance trends, facilitating easier comparison and analysis of the data. These visualizations can assist engineers and decision-makers in identifying areas for improvement or optimization in both modes of operation.

TABLE II : TRAIL VS SPEED (EARLY MORNING)

Trail/speed limit	30-40 (km/hr.)	50-60 (km/hr.)	80-90 (km/hr.)
Trail 1 in Km	17	19	7
Trail 2 in Km	19	20	10
Trail 3 in Km	18.9	19	9

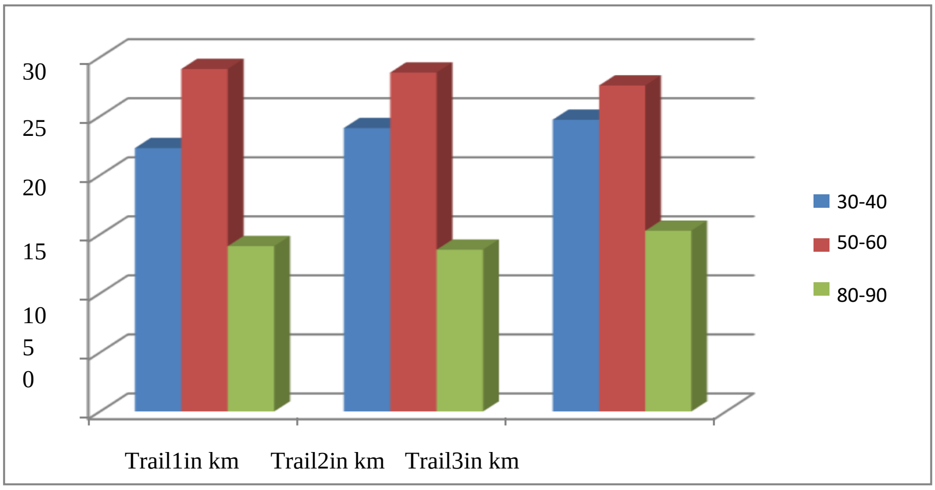


Fig.5. Bar chart-Trail vs. speed in early morning

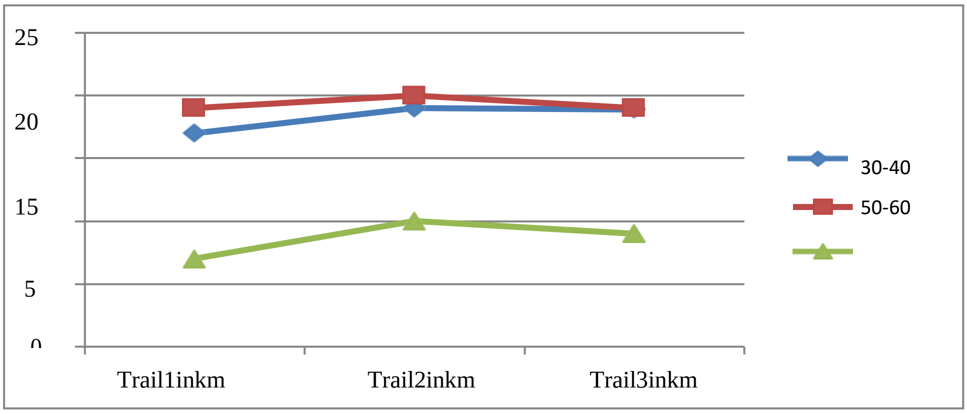


Fig. 6, X-Y plot for Trial vs Speed in early morning

TABLE III: TRAIL VS SPEED (AROUND NOON)

Trail/speed limit	30-40 (km/hr.)	50-60 (km/hr.)	80-90 (km/hr.)
Trail 1 in Km	22.3	29	14
Trail 2 in Km	24	28.7	13.7
Trail 3 in Km	24.7	27.6	15.3

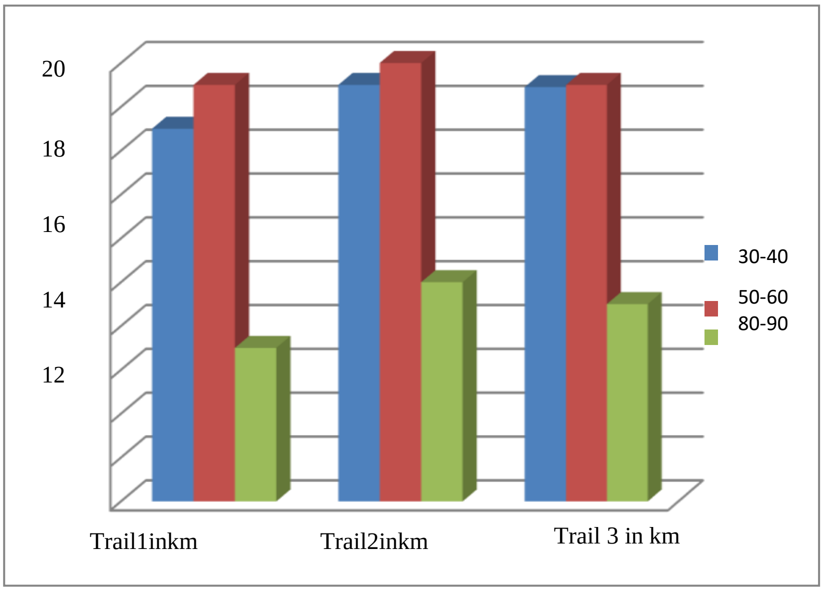


Fig. 7, Bar chart- Trail Vs Speed at 12.00 Noon

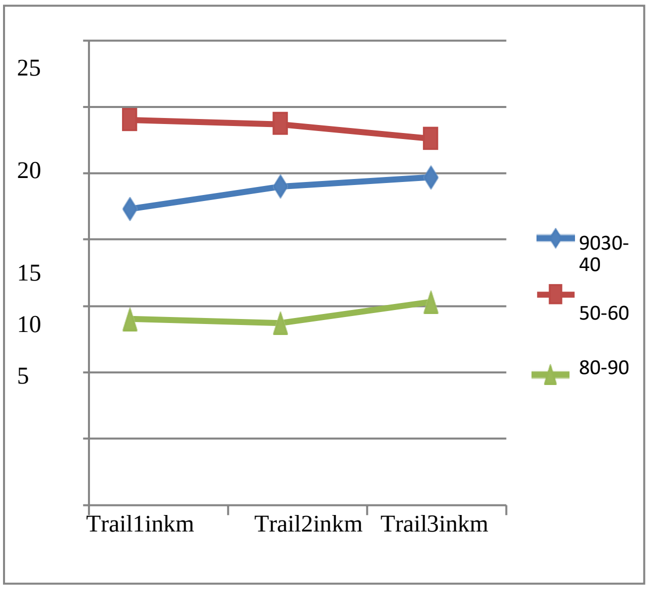


Fig. 8, X-Y plot for Trial vs Speed at 12.00 Noon

Table II, showcases the results obtained from conducting three distinct trail runs with the two-wheeler across different speed ranges: 30-40 km/h, 50-60 km/h, and 80-90 km/h during the early morning hours. Through experimental analysis, it is evident that the average speed range of 50-60 km/h exhibits optimal performance characteristics. This finding suggests the efficiency and effectiveness of the vehicle's operation within this speed range.

Figures 5 and 6 complement the analysis by providing visual representations in the form of bar and XY plots, respectively, further elucidating the performance trends across the various speed ranges. These visualizations aid in better understanding the relationship between speed and performance metrics, contributing valuable insights for future evaluations and optimizations.

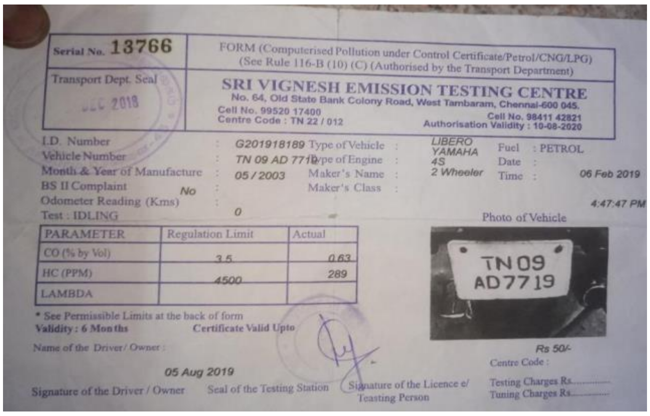
Table 3 showcases the results obtained from conducting three distinct trail runs with the two-wheeler across different speed ranges: 30-40 km/h, 50-60 km/h, and 80-90 km/h during the noon – maximum temperature hours. Through experimental analysis, it is evident that the average speed range of 50-60 km/h exhibits optimal performance characteristics of 28.7 km/h and 27.6km/h. This finding suggests the efficiency and effectiveness of the vehicle's operation within this speed range.

Figures 7 and 8 complement the analysis by providing visual representations in the form of bar and XY plots, respectively, further elucidating the performance trends across the various speed ranges. These visualizations aid in better understanding the relationship between speed and performance metrics, contributing valuable insights for future evaluations and optimizations.

V. OVERALL RESULT

In addition to evaluating changes in mileage, this test also examines other performance metrics such as engine efficiency, emissions output, and overall vehicle performance with and without the presence of hydrogen. By analyzing these parameters, researchers can assess the impact of hydrogen utilization on the vehicle's operational characteristics, including its power delivery, responsiveness, and environmental impact. Furthermore, conducting road tests provides real-world insights into how hydrogen integration affects the vehicle's handling, stability, and overall driving experience. This comprehensive evaluation helps determine the feasibility and practicality of incorporating hydrogen technology into existing vehicle systems, paving the way for potential advancements in alternative fuel solutions.

VI. EMISSION TEST RESULT



Serial No. 13766

FORM (Computerised Pollution under Control Certificate/Petrol/CNG/LPG)
(See Rule 116-B (10) (C) (Authorised by the Transport Department)

Transport Dept. Seal

DEC 2018

SRI VIGNESH EMISSION TESTING CENTRE
No. 64, Old State Bank Colony Road, West Tambaram, Chennai-600 045.
Cell No. 99520 17400
Centre Code : TN 22 / 012
Cell No. 98411 42821
Authorisation Validity : 10-08-2020

I.D. Number : G201918189
Vehicle Number : TN 09 AD 7719
Month & Year of Manufacture : 05 / 2003
BS II Complaint : No
Odometer Reading (Kms) : 0
Test : IDLING

Type of Vehicle : LIBERO
Type of Engine : YAMAHA
Maker's Name : 4S
Maker's Class : 2 Wheeler

Fuel : PETROL
Date : 06 Feb 2019
Time : 4:47:47 PM

PARAMETER	Regulation Limit	Actual
CO (% by Vol)	3.5	0.63
HC (PPM)	4500	289
LAMBDA		

* See Permissible Limits at the back of form
Validity : 6 Months Certificate Valid Upto 05 Aug 2019
Name of the Driver/ Owner :

Photo of Vehicle

TN 09
AD 7719

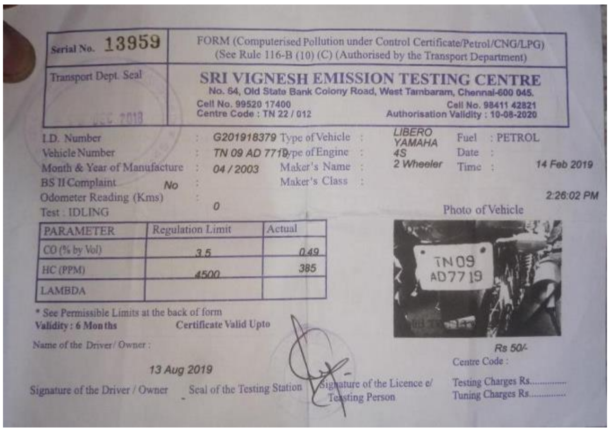
Rs 50/-
Centre Code :
Testing Charges Rs............
Tuning Charges Rs............

Signature of the Driver / Owner
Seal of the Testing Station
Signature of the Licence e/ Teasting Person

Fig. 9, Emission test report without installation of aqua Silencer

In Figure 9, the test is conducted at the beginning of the experiment, depicting the actual emission levels of the bike without any modifications. Figure 10 illustrates the emissions test conducted after installing the aqua silencer, showcasing the bike's emission levels with this modification in place. Subsequently, in Figure 11, the test is conducted after introducing hydrogen as a secondary fuel, displaying the emissions test results of the bike post-aqua silencer installation and hydrogen integration.

These figures serve to compare the emission levels of the bike under different experimental conditions, providing valuable insights into the effectiveness of various modifications, such as the aqua silencer and hydrogen integration, in reducing emissions. Additionally, they offer a visual representation of the environmental impact of these modifications, aiding in assessing their sustainability and contribution to cleaner air quality.



Serial No. 13959

FORM (Computerised Pollution under Control Certificate/Petrol/CNG/LPG)
(See Rule 116-B (10) (C) (Authorised by the Transport Department)

Transport Dept. Seal

SRI VIGNESH EMISSION TESTING CENTRE
No. 64, Old State Bank Colony Road, West Tambaram, Chennai-600 045.
Cell No. 99520 17400
Cell No. 98411 42821
Centre Code : TN 22 / 012
Authorisation Validity : 10-08-2020

I.D. Number : G201918379
Vehicle Number : TN 09 AD 7719
Month & Year of Manufacture : 04 / 2003
BS II Complaint : No
Odometer Reading (Kms) : 0
Test : IDLING

Type of Vehicle : LIBERO
Type of Engine : YAMAHA
Maker's Name : 4S
Maker's Class : 2 Wheeler

Fuel : PETROL
Date : 14 Feb 2019
Time : 2:26:02 PM

PARAMETER	Regulation Limit	Actual
CO (% by Vol)	3.5	0.49
HC (PPM)	4500	385
LAMBDA		

* See Permissible Limits at the back of form
Validity : 6 Months
Certificate Valid Upto 13 Aug 2019
Name of the Driver / Owner :

Photo of Vehicle

TN 09
AD 77 19

Rs 50/-
Centre Code :
Testing Charges Rs............
Tuning Charges Rs............

Signature of the Driver / Owner
Seal of the Testing Station
Signature of the Licence e/ Testing Person

Fig.10 Emission test report after installation of an aqua silencer without hydrogen

Table Iv- displays emission values obtained from three different experiments: one with conventional silencers, another with aqua silencers, and a third with aqua silencers and secondary fuel hydrogen. According to the experiments, the configuration with aqua silencers and secondary fuel hydrogen resulted in significantly lower levels of carbon monoxide and hydrocarbons. Additionally, Table 4 provides a comprehensive comparison of emissions across various experimental setups, allowing for a detailed analysis of the effectiveness of different emission reduction strategies.The data presented in the table enable researchers and policymakers to assess the environmental impact of adopting alternative technologies such as aqua silencers and hydrogen supplementation in vehicle exhaust systems. Furthermore, the findings highlight the potential of these technologies to contribute to overall air quality improvement and reduce the carbon footprint of transportation. By quantifying emission reductions achieved through each experimental setup, Table 4 serves as a valuable reference for guiding future research and development efforts aimed at enhancing vehicle emissions control measures. Moreover, the results underscore the importance of continuous innovation in emission control technologies to address environmental challenges associated with transportation and promote sustainable mobility solutions.

SRI KAMAKSHI EMISSION TESTING CENTRE

Test : IDLING

Validity : 6 Months

Fig. 11. Emission test report with hydrogen as a secondary fuel

TABLE IV: EMISSION VALUES

Stages / Emission	**Carbon monoxide**	**Hydro-carbon in ppm**
With Conventional Silencer	0.63	289
With Aqua Silencer	0.49	28.7
With Acqua Silencer and Secondary fuel - hydrogen	24.7	27.6

X. APPLICATIONS

A. *Low Friction and Pumping Losses*

Up to 40% of the cranking energy in a current automobile is spent turning the engine over against friction and pumping losses. The opportunity to make gains in this area with a new hydrogen IC engine design cannot be ignored. The elimination of the valve drive train and sliding piston friction account for a significant reduction in engine friction. The wide range of fuel-air equivalency ratios at which hydrogen can be ignited presents the potential to control engine output with a minimum of engine throttling thereby reducing pumping losses.

B. *Long Service Life and Low Manufacturing Cost*

There isalways a durability/cost ratio trade-off in the manufacturing of engine components. An engine with few components is more cost-effective to develop and manufacture to meet a set standard of reliability and durability. Modular assembly minimizes product development time and manufacturing cost. It is desirable to avoid the added cost and weight of power-boosting mechanisms such as superchargers and intercoolers.

C. Thermal Control

Complete thermal control of the combustion environment is fundamental to the efficient operation of the engine. Control of head and piston surface temperature is essential as well as the surface that the induction air or air/fuel charge comes in contact with as it enters the working chamber of the engine.

XI. CONCLUSION

The aqua silencer is highly effective in reducing emission gases from engine exhaust by utilizing a perforated tube and charcoal. The use of a perforated tube ensures that back pressure remains constant, while simultaneously reducing sound levels. The performance of the aqua silencer is comparable to that of a conventional silencer, making it suitable for use in both two-wheelers and industries. Furthermore, it offers smokeless and pollution-free emissions, and its cost-effectiveness makes it an attractive option.

By utilizing water as a medium, the aqua silencer can effectively lower sound levels. However, incorporating activated charcoal into the water allows for greater control over exhaust emissions. Despite the use of a perforated tube, fuel consumption remains consistent with that of a conventional system.

The development of advanced hydrogen internal combustion engine (H_2ICE) designs has the potential to significantly improve overall vehicle efficiency, impacting the adoption of hydrogen-powered vehicles in future hydrogen economies. However, the design of an appropriate IC engine specifically tailored for hydrogen fuel remains unexplored, leaving the long-term outcome uncertain. Additionally, while hydrogen IC engines may offer lower thermal efficiency compared to current fuel cell technology, the overall fuel life cycle cost, from manufacture to disposal of the H_2ICE, must be carefully considered and weighed against potential benefits.

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DECLARATION

Declaration	Suggestions
Funding/ Grants/ Financial Support	**If not applicable:** No, I did not receive it.
Conflicts of Interest/ Competing Interests	**If not applicable:** No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	**If not applicable:** No, the article does not require ethical approval and consent

	to participate with evidence.
Availability of Data and Material/ Data Access Statement	.**If not applicable:** Not relevant.
Anthors Contributions	**If applicable and having more than two authors: study conception and design:** Sivakumar Karthikeyan; **data collection and experiments, analysis and interpretation of results,draft manuscript preparation:** Sivakumar Karthikeyan and *Mithunn Balaji. S.,*

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