Study of a4-Stroke S.I. Engine Performance Using Gasoline & Hydrogen Fuel

[1]Nilesh Kumar Rajwade, [2]Krishan Pal, [3]Don Banjara, [4]Rupendra Kumar Sonkar, [5]Y. Rajesh

B. Tech, Department of Mechanical Engineering, The ICFAI University, Raipur, C.G., India
Email: [1]nilumum2020@gmail.com, [2]krishanpal407@gmail.com, [3]donbanjara3112@gmail.com, [4]rsonkar.19apr@gmail.com, [5]rajeshkumar6281@gmail.com

Abstract - Output from engine is concerned with fuel type and fuel quality. The present study gives a comparative analysis of engine performance of 4-stroke spark-ignition engine using gasoline and hydrogen as fuel. Primarily the description of the hydrogen engine and gasoline engine has been presented. It is concluded from various research review that Hydrogen is high flammable with high flammability limits, it is required low ignition energy and also required less ignition timing. It is found from the present study that the flammable mixture of hydrogen fuel with air disperse rate is more than the gasoline fuel, reduced reliance on imported oil and reduces the emissions.

Keywords: - 4-stroke Engine, Hydrogen, Gasoline.

I. INTRODUCTION

An engine is a device which produces useful form of energy or convert available energy into useful mechanical energy. The heat engine, includes external combustion engine i.e. boiler, and internal combustion engine i.e. a steam engine. In I.C. engine fuels are burned to produce thermal energy, further it is converted in to mechanical energy. The engine classification is based on the types of fuel used and number of strokes produced in engine. It may be classified as low-speed, medium-speed, high-speed but these term are depends upon the type of engine being described. Several researches carried out in this field to compare the performance of engine when using gasoline and hydrogen as fuel. To suggest the suitability various aspects has been included in the study.

II. WORKING OF 4 -STROKE S.I. GASOLINE ENGINE

Initially, the piston is at Top Dead Centre (TDC) then the suction stroke starts. When the piston muves from Top Dead Centre (TDC) to Bottom Dead Centre (BDC) the pressure inside the cylinder is below the atmosphere. The fuel air mixture comes into the cylinder volume through the inlet valve. The inlet valve will close and the fuel gets compressed when the piston moves from Bottom Dead Centre (BDC) to Top Dead Centre (TDC) at the compression stroke the pressure and temperature of mixture rises. After compression stroke ignition takes place from the spark plug. The combustion starts and again the piston will move from Top Dead Centre to Bottom Dead Centre. From this, expansion stroke mechanical power is generated. After the expansion stroke the exhaust gas vents through the exhaust valve [1].

III. WORKING OF HYDROGEN ENGINE

All internal combustion engine depends upon the exothermic chemical process of combustion or burning the reaction of a fuel with ambient air oxygen taking place inside the engine combustion chamber. while most of the fuel used today hydrocarbons and these are drive from crude oil (like:- diesel , gasoline and liquefied petroleum gas)or from natural gas also liquid and gaseous biofuels (like:- ethanol) or hydrogen (either in compressed from as CGH 2 or in liquefied from such as LH 2) can be used.

Hydrogeninternal combustion engines are fully based on ICEs design for the natural gas (CNG).Exhaust gas emission is extremely low. No greenhouses gases are emitted, due to absence of carbon material. It depends upon the fuel production paths, hydrogen ICEs can be operated fully independently of fossil fuels.

IV. FUEL PROPERTIES–

1. Range of flammability

2. Low ignition energy

3. Small quenching distance

4. High auto ignition temperature

5. High flame speed

6. High diffusivity

7. Low density

1. Range of flammability: -The flammability limits (= possible mixture composition for ignition and flame propagation) are very wide for hydrogen i.e. 4% -75% hydrogen in the mixture compared to gasoline i.e. 1% -7.6%. This reveals that the load of the engine can be controlled by the air to fuel ratio for diesel engine. The engine can be run with a wide open throttle all time, resulting in a higher efficiency [9].

2. Low ignition energy: - hydrogen has very low ignition energy. The amount of energy needed to ignite hydrogen is about one order of magnitude less than that required for gasoline. This enables hydrogen engine to ignite lean mixture and ensure prompt ignition. [12]

3. Small quenching distance: - hydrogen has a small quenching distance, smaller than gasoline. Hydrogen flames travels closer to the cylinder wall than other fuels. it is extremely difficult to slake a hydrogen flame than gasoline flame. [12]

4. High auto ignition temperature: - the temperature does not exceed hydrogen auto ignition temperature without causing premature ignition. The absolute final temperature limits the compression ratio. The high auto ignition temperature of hydrogen allows larger compression ratio to be used in hydrogen engine than in a hydrocarbon engine. [12]

5. High flame speed: -at stoichiometric ration hydrogen has high flame speed. Under some condition, hydrogen flame speed is nearly an order of magnitude higher than that of gasoline. This means that hydrogen engine can more closely approach the thermodynamically ideal engine cycle. In the leaner mixture the flame velocity decrease significantly. [12]

6. High diffusivity: - hydrogen has very high diffusivity. It has ability to disappear in air is considerably greater than gasoline and is advantageous there are two main reasons, First reason is that it facilitates the formation of a uniform mixture of fuel and air. Second reason is thatif a hydrogen leak develops, the hydrogen disperses rapidly. Thus, unsafe condition can either be avoided or minimized. [12]

7.Low density: -Hydrogen density is very low. There are two problems when, used in an internal combustion engine. First problem is to store enough hydrogen in a very large volume, necessary to give a vehicle an adequate driving range. Second problem is the energy density of a hydrogen air mixture, hence the power output is low. [12]

V. GASOLINE

At first we know about gasoline, gasoline a mixture of volatile, flammable liquid hydrocarbons, a petroleum derivative, also used as fuel for internal- combustion engines. Gasoline by-product of petroleum industries became the preferred automobile fuel because of its high energy of combustion and capacity to mix readily with air in carbonator [2].

Table No 1 : Gasoline combustion property [17-19]

Property	**Gasoline**
H- content (% weight)	12-15
Density kg/m^3 (ambient,25^{0}C)	730
Vapour density (compared to air)	Heavier
Boiling point (temperature ^{0}C)	27-225
Flame propagation (speed m/s)	0.5
Motor octane number	80-90
Research octane number	92-98
Motor mass (kg/mole)	110
Stoichiometric mixture density (kg/m^3)	1.38
Lower heating value (MJ/kg)	43.6
Lower heating value of stoichiometric mixture (MJ/kg)	2.83
Flammability limits (vol.% in air)	1.3-7.1
Spontaneous ignition temperature (^{0}C)	257^0

Table No 2 : Thermodynamic properties of petrol [11]

Stoichiometric ratio	14.2
Octane number	96
Higher heating value (MJ/kg)	45
Lower heating value (MJ/kg)	42.2
Density @ 25^0 C kg/m^3 (DI 51757)	749
Molecular weight (kg/kmol)	106.2

Gasoline engine: - any of a class of internal combustion engines that generate power by burning a volatile liquid fuel (gasoline or a gasoline mixture such as ethanol) with ignition initiated by an electric spark. gasoline engines can be built to meet the requirement of practically any conceivable power-plant application, the most important being passenger automobile, small trucks and buses, general aviation aircraft, outboard and small inboard marine units, moderate-sized stationary pumping, lighting plants, machine tools, and power tools. Four-stroke gasoline engine power the vast majority of automobiles, light trucks, medium-to-large motorcycles, and lawn mowers. two -stroke gasoline engines are less common, but they are used for small outboard marine engines and in many handled landscaping tools such as chain saws, hedge trimmer, and leaf blowers [4]

VI. LITERATURE REVIEWS

Various research papers have been studied in the concerned field and found that the effect of parameter like load capacity, fuel consumption, and emission has the significant contribution over the engine performance.

Jehad Ahmad Yamin et. al. performed analysis for internal combustion engine, with a compression ratio that can be varied between 5:1 and 8:1. The engine used was water-cooled, single-cylinder, four stroke spark-ignition engine that has a swept volume of 580 cm^3. Experimental values of various parameters have been mentioned below. To able to use the engine with gashouse fuel, a special mixture which consist of a throat and butterfly valve only is fitted in place of the carburetor to control the flow of fuel. The gaseous fuel is introduced through hole at tip of the throat. The engine testing condition were as shown in the table-

Table No 3 : Engine test condition [5]

Engine parameter	Value
Engine speed	1500-2500 rpm
Compression ration	9:1 (fixed)
Spark advance variable	Variable
Throttle position	Wide open (WOT)

Estimated performance of the engine using gasoline compared with hydrogen fueled engine. [5]

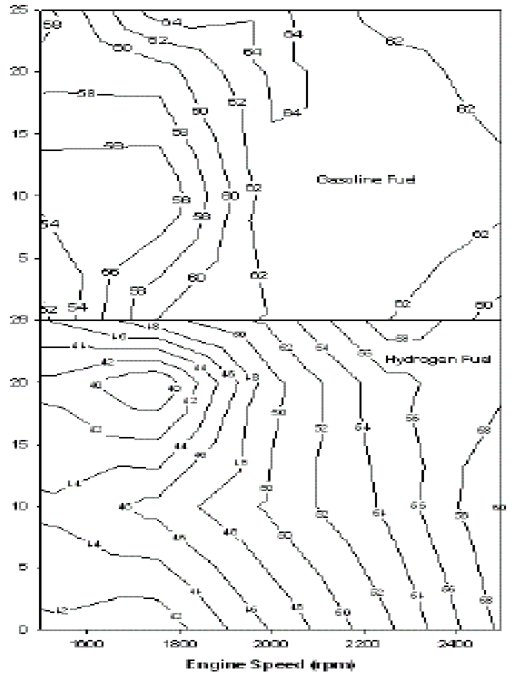

Figure1: Variation of volumetric (%) with engine speed at various ignition timing[5]

Figure1 shows the volumetric efficiency for both gasoline and hydrogen fuels at first noticed is the reduction in the engine volumetric efficiency with hydrogen fuel. The inlet manifold is usually supplied with some heat to expand more than liquid gasoline inside the engine, leading to a drop in the volumetric efficiency of hydrogen fired engine further the displacement of air by the larger volume hydrogen occurs due to heated inlet manifold. It was founded by researchers that a stoichiometric mixture of hydrogen-air-fuel contain 30% hydrogen by volume, whereas gasoline-air stoichiometric mixture the percentage is 20% of fully vaporized gasoline by volume. Author noticed that the power output of a direct injected hydrogen engine vehicle is 20% more than a gasoline engine vehicle and 42% more than a hydrogen engine vehicle using a carburetor.

David M. Smiadak et. al. in his paper experiment analysis has been reported of a 4- stroke gasoline engine. In which experimentally determination has been made for speed, torque, and exhaust temperature as well as air and fuel consumption. The experimental data recorded for each trial is shown table below as-

Table No 4 : Experimental data, varying engine speed [14]

Test number	Speed (rpm)	Torque (N.m.)	Fuel time for 8 ml (s)	Air mm H_2O	Exhaust temp. (^0C)
1	5,500	2	31.53	9.5	735
2	4,750	3.9	34.9	10.5	775
3	4,100	5.3	32	10	710
4	3,300	7.4	30.97	9	655
5	2,800	8.5	45.13	8	630
6	1,500	7.1	69.88	4	460

Using the values, author suggested that the mass flow rate of the air can be calculated by experimental and theoretical method.[14]

Jiwak G. Suryawanshi et. al. reported that the reserves of fossils fuels continually decreasing due to its faster exploration and unanimous uses. Author mentioned that to improve low burning velocity and poor combustion stability of natural gas fueled engine hydrogen blending with CNG can be looked upon as a good alternative fuel. The burning velocity increases exponentially with the increase of hydrogen fraction in the fuel.

Erol Kahraman et. al. Hydrogen is an odorless, colorless gas. With molecular weight of 2.016, hydrogen is the lightest element. Its density is about 14 times less than air (0.08376 kg/m^3at standard temperature and pressure). Hydrogen is liquid at temperatures below 20.3 K (at atmospheric pressure). Hydrogen has the highest energy content per unit mass of all fuels - higher heating value is 141.9 MJ/kg, almost three times higher than gasoline. Some important properties of hydrogen are compiled in Table 4.

The specific physical characteristics of hydrogen are quite different from those common fuels. Some of those properties make hydrogen potentially less hazardous, while other hydrogen characteristics could theoretically make it more dangerous in certain situation. [16]

Table No 4 : Variables during experiment

Property	Hydrogen	Gasoline
Density at 1atm., 300 K	0.082	5.11
Stoichiometric composition in air (%volume)	29.53	1.65
Number of moles after combustion to before	0.85	1.085
LHV (MJ/kg)	119.7	44.79
Combustion energy/kg of stoichiometric mixture (MJ)	3.37	2.79

VII. COMPARISION OF GASOLINE AND HYDROGEN ENGINES

The difference between a hydrogen and gasoline engine include hardened valves and valve seats, stronger connecting rods, non-platinum tipped spark plugs, a higher voltage ignition coil, fuel injectors designed for a gas instead of a liquid, larger crankshaft damper, stronger had gasket material, modified, positive pressure supercharger, and a high temperature engine oil. All modification would amount to about one point five times (1.5) the current cost of a gasoline engine. These hydrogen end burn fuel in the same manner that gasoline engine do [6].Hydrogen is the one of the most promising fuels. It's give clean burning characteristic and gives the better performance has compare to other alternative fuels. Shown by the table below. [13]

Table No 5 : Properties comparison of hydrogen with gasoline

Properties	Hydrogen	Gasoline
Auto ignition temperature (K)	858	714
Minimum ignition energy (mJ)	0.02	0.24
Flammability limits (volume % in air)	4-75	1.2-7.1
Molecular weight (g)	2.016	107
Density (kg/m^3)	0.0899	730
Stoichiometric A/F ratio (mass basis)	34.4	14.7
Flame velocity (cm/s)	270	30-50
Specific gravity	0.091	0.739
Adiabatic flame temperature (K)	2318	2470
Quenching gap (cm)	0.064	0.2
Heat and combustion (MJ/kg)	120	43.4
Boiling point (K)	20.27	473

VIII. DESIGN PARAMETERS OF FOUR STROKE ENGINE

1. Cylinder Swept Volume (V_C) –

V_C = Cylinder Area × Stroke Length

$$V_C = A_c \times L = \frac{\pi}{4} \times d^2{}_c \times L$$

Where:

V_C= cylinder swept volume (cm^3 (cc) or L).

A_C = cylinder area [cm^2 or cm^2/100]

D_C= cylinder diameter [cm or cm/10]

L= stroke length (the distance between the TDC and BDC) [cm or cm/10].

2. Engine swept volume (V_e) : -

V_e = total cylinders' swept volume of the engine

$$Ve = n \times A_C$$

$$Ve = n \times A_C \times L = n \times \left(\frac{\pi}{4} d^2{}_c\right) \times L$$

Where:

Ve = engine swept volume [cm^3(cc) or L]

N = number of cylinders

V_C = cylinder swept volume [cm^3(cc) or L]

A_C = cylinder area [cm^2 or cm^2/100]

D_C = cylinder diameter [cm or cm/10]

3. Compression ratio (r):-

$$r = \frac{cylider\ volume\ at\ BDC}{cylinder\ volume\ at\ TDC}$$

$$r = \frac{(cylinder\ volume + cylinder\ clearance\ volume)}{cylinder\ clearance\ volume}$$

$$r = \frac{V_3 + V_C}{V_C} = 1 + \frac{V_3}{V_C}$$

Where:

r = compression ratio

V_3 = cylinder swept volume (combustion chamber volume) [cc, L, or m^3]

V_C = cylinder volume [cc, L, or m^3]

4. Engine Volumetric Efficiency (η_V):-

$$\eta_v = \frac{volume\ of\ air\ taken\ into\ cylinder}{maximum\ possible\ volume\ in\ the\ cylinder}$$

$$\eta_V = \frac{V_{air}}{V_C}$$

Where:

η_v = volumetric efficiency

V_{air} = volume of air taken into cylinder [cc, L, or m^3]

V_C = cylinder swept volume [cc, L, or m3]

5. Engine Indicated Torque (T_i):-

$$T_i = \frac{work\ (w)}{angle\ (\theta)}$$

$$= \frac{work\ per\ one\ revolution}{angle\ of\ one\ revolution}$$

$$= \frac{force \times distance}{2\pi} \times n$$

$$T_i = \frac{(imep \times A_C) \times L \times n}{2\pi \times z} = \frac{imep \times V_e}{2\pi \times z}$$

Where:

T_i = engine indicated torque [Nm]

$imep$ = indicated mean effective pressure [N/m^2]

$AC = cylinder\ area\ [m2]$

L = stroke length [m]

Z = 1(for 2 stroke engines), 2(for 4 stroke engines)

n = number of cylinders

θ = Crank shaft angle [1/s]

6. Engine Indicated Power (P_i) :-

$$P_i = \frac{imep \times A_C \times L \times n \times N}{Z \times 60}$$

$$P_i = \frac{imep \times (A_C \times L) \times n \times N}{Z \times 60} = \frac{imep \times (V_C \times n) \times N}{Z \times 60}$$

$$P_i = \frac{imep \times V_e \times N}{Z \times 60}$$

Where:-

$Imep$ = Is the indicated mean effective pressure [N/m^2]

A_C = cylinder area [m^2]

L = stroke length [m]

n = number of cylinders

N = engine speed [rpm]

z = 1 (for 2 stroke engines) & 2 (for 4 stroke engines)

V_C= cylinder swept volume [m^3]

V_e= engine swept volume [m^3]

T_i = engine indicated torque [Nm]

ω = engine angular speed [1/s]

7. Engine Mechanical Efficiency (n):-

$$\eta_m = \frac{Engine\ Brake\ Power}{Engine\ Indicated\ Power}$$

$$\eta_m = \frac{P_b}{P_i}$$

$$\eta_m = \frac{P_i - P_f}{P_i} = 1 - \frac{P_f}{P_i}$$

Where:-

η_m = mechanical Efficiency

P_b = engine brake power [kW]

P_i= engine indicated power [kW]

P_f =Engine frictional power [kW]

8. Engine Specific Fuel Consumption (SFC):-

$$SFC = \frac{mass\ of\ fuel\ consumption}{engine\ brake\ power}$$

$$SFC = \frac{FC}{P_b}$$

Where:-

SFC = specific fuel consumption [(kg/h)/kW, kg/ (3600s ×kW), kg/ (3600kJ)]

FC = fuel consumption [kg/h]

P_b = brake power [kW]

9. Engine Thermal Efficiency (η_{th}):-

$$\eta_{th} = \frac{brake\ power}{fuel\ power}$$

$$\eta_{th} = \frac{3600 \times P_b}{FC \times CV}$$

Where:-

η_{th} = thermal efficiency

P_b = Brake power [kW]

FC = fuel consumption

[kg/h = (fuel consumption in L/h) × (ρ in kg/L)]

CV = calorific value of kilogram fuel [kJ/kg]

ρ = relative density of fuel [kg/L]

IX. RESULTS & CONCLUSION

Despite of good thermal efficiency of gasoline engine and power output it is obvious that its emission is dangerous to environment and living beings. Burning of fossil fuels will definitely produce the harmful gases. From the various literatures it has been observed that these emissions can be avoided when implementing hydrogen as a fuel in to internal combustion engine. The final product of combustion will be the water vapour or its droplet. The mechanical & thermal efficiency may vary somehow than the gasoline engine but hydrogen as fuel to IC engine will not put the environment in danger. Further it is needed to work on it. The modification in engine and fuel storage is needed to optimize for better performance and ease to use.

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