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# A Theoretical Review on the Methods and Production of Gaseous Fuels Usage in an Internal Combustion Engines

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## Abstract:
An increase in human activities and high population growth have significantly increased the world's energy source of demands. The major source of energy for the world today is from fossil fuels, which are polluting and degrading the environment due to the emission of greenhouse gases. Usage of Gaseous fuels such as acetylene and hydrogen in an IC engines with the methods and production is going to be analyzed in this paper.Acetylene and hydrogen gas is an identified efficient energy carrier and can be obtained through various renewable sources. An overview of acetylene and hydrogen production by various methods and its usage in the Compression ignition engine is going to be reviewed. In the review, the analysis of properties such as density, Cetane number, calorific value, stoichiometric air fuel ratio, Auto ignition temperature, Flammability limits, ignition energy, and maximum deflagration speed differs for both the fuels. In addition to that, the method of inducting both the gaseous fuels in CI engines is to be focused in its usage. Both the gaseous fuels are very hazardous in its usage and implementation in CI Engines. Also the safety method of inducting gaseous fuels such as flame trap, flame arrestors to resist the back fire is also analyzed. The various analysis such as performance, emission and combustion characteristics by implementing / inducting this gaseous fuel in CI engines is focused in this review.

*Keywords* — Acetylene, Hydrogen, CI Engine

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## I. INTRODUCTION

Considering the energy situation today, research is concentrated on the reduction of conventional fuel consumption and lowering of harmful emission. Use of gaseous fuels in the internal combustion engine has a strong appeal from the pollution point of view, which could assist in reducing global warming. Over the past two decades, there has been a considerable effort in the world to develop and introduce alternative gaseous fuels to replace conventional fuel. The research work on utilization of gaseous fuels such as methane, propane, acetylene, ethylene and hydrogen in diesel engine reveals that the maximum amount of gas consumption is limited to the onset knock. Gaseous fuels such as LPG, CNG, have been commercialized and more research work has been carried out to use acetylene and hydrogen in internal combustion engine. However the technology and cost are the two barriers influencing the utilization of hydrogen as a commercial fuel. Acetylene and hydrogen is chosen as an alternative fuel in the present study to check the feasibility of using it in internal combustion engine. Acetylene possesses similar properties of hydrogen, which can win the battle against hydrogen.

## II.Gaseous fuel as an alternate fuel

### 2.1 Acetylene as an Alternative Fuel

  

Acetylene ($C_2H_2$) , when in cylinders is known as DA (dissolved acetylene). Acetylene is colourless, invisible, slightly lighter than air, non toxic with slight garlic like odour. Acetylene is used primarily as a raw material in the production of chemicals. It is used for Oxy-Acetylene welding, cutting and heat treatment.

#### 2.2 Hydrogen as an Alternate Fuel

Hydrogen is a colorless, odorless, tasteless, highly flammable gas. It is also the lightest-weight gas. Since hydrogen is noncorrosive, special materials of construction are not usually required. Hydrogen is colorless as a liquid. Its vapors are colorless, odorless, tasteless, and highly flammable. Liquid hydrogen is noncorrosive.

### 3.Important gaseous fuel Properties

#### 3.1Auto ignition temperature

The auto ignition temperature is the minimum temperature required to initiate self-sustained combustion in combustible fuel mixtures in the absence of a source of ignition. For Acetylene and Hydrogen, the auto ignition temperature is 330 °C and 572°C that makes it difficult to ignite acetylene-air mixture and hydrogen –air mixture on the basis of heat alone without some additional ignition sources**.**

#### 3.2 Ignition energy

Ignition energy is the amount of external energy that must be applied in order to ignite a combustible fuel mixture. Energy from an external source must be higher than the auto ignition temperature and must be of sufficient duration to heat the fuel vapour to its ignition temperature. Common ignition sources are flames and spark. Ignition energy for acetylene is 0.019 mJ and for hydrogen is 0.2 mJ .

#### 3.3 Burning speed

Burning speed is the speed at which a flame travels through combustion gas mixture. Burning speed indicates the severity of an explosion since high burning velocities have a greater tendency to support the transition from deflagration to detonation in long tunnels or pipes. Burning speed varies with gas concentration and drops at both ends of the flammability range.

#### 3.4 Flame characteristics

Pure acetylene is odourless, but acetylene of ordinary commercial purity has distinctive, garlic like smell. Acetylene burns with air with an intensely hot, luminous and smoky flame. The ignition temperatures of acetylene mixtures vary according to composition, pressure, water vapour content and initial temperature.

#### 3.5 Problems associated with gaseous fuel

The problems associated with the use of gaseous fuel are

1. Premature ignition
2. Flash back

#### 3.5.1 Premature Ignition

The primary problem that has been encountered in the development of operational acetylene and Hydrogen engines is premature ignition. Premature ignition is a much greater problem in acetylene fueled and hydrogen fuelled engines than in other IC engines, because of acetylene's and hydrogen's lower ignition energy, wider flammability range. Premature ignition occurs when the fuel mixture in the combustion chamber becomes ignited before ignition by the source results in an inefficient, rough running condition. It is a much greater problem in acetylene and hydrogen-fueled engines than gasoline fueled engines.

  

**3.5.2 Flash back**

If the premature ignition occurs near the fuel intake valve, the resultant flame travels back into the induction system. Backfire can occur when there is a valve overlap between the opening of the intake and exhaust valve.

**3.5.3 Handling and storage**

Acetylene and hydrogen is unstable and cannot be stored at high pressures in the same way as other gases like oxygen and nitrogen in normal cylinders . Acetylene and hydrogen burns in air with a smoky flame. It develops a lot of heat at high temperature. Mixture is very easy to ignite or explode with a small flame or a hot spot. When heated or compressed above normal operating limits, acetylene may explode.

## 4.Production methods of Gaseous fuels

**4.1Production of Acetylene**

Acetylene can be produced by several processes and some of them are described in this section. Acetylene is primarily produced by any of the following methods.

1. By reaction of water with calcium carbide
2. By passing hydrocarbon with electric arc.
3. Partial combustion of methane with air /oxygen.

**4.1.1 Hydrolysis of Calcium Carbide to Acetylene**

The reaction of calcium carbide with water is significantly exothermic.

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2 + 31.0 kcal$$

Pure calcium carbide on treatment with stoichiometeric amount of water at 180˚ C and 1 atmospheric will evolve 484 kcal/kg carbide. A commercial grade of $CaC_2$ (equivalent to 3000 liters $C_2H_2$ /kg) will give a heat of 429 kcal .The carbide water reaction will heat the reaction mass to over 700°C. In commercial practice, the rate of generation of acetylene is 0.03 $m^3$/hr by using 0.5 kg carbide and 3.8 liters of water.

Generators are characterized by water containing reactor chamber carbide hopper, acetylene water scrubber and gas storage tank. The generators are protected with flash arrestors to prevent acetylene deflagration and have pressure relief valve.

**4.2 Production of Hydrogen**

Hydrogen can be produced from diverse, domestic resources, including fossil fuels, biomass, and water electrolysis with electricity. Hydrogen can be produced in a different number of processes and it is stored in a cylinder and it can be used as an alternate fuel in CI Engines Thermo chemical processes use heat and biomass, or from materials like water..Water ($H_2O$) can also be split into hydrogen ($H_2$) and oxygen ($O_2$) using electrolysis or solar energy.

## 5. Properties of Acetylene, Hydrogen compared with Diesel

The properties of Acetylene and Hydrogen in comparison with Diesel are shown in Table 1.
The properties of acetylene and hydrogen in comparison with Diesel with respect to the various properties such as density, calorific value, flame speed, ignition energy, flammability limits, auto ignition temperature is shown in the table for both acetylene and hydrogen.

## 6.Method of inducting gaseous fuel in Internal Combustion Engines

There are several methods of inducting gaseous fuel in CI Engines.

1. Direct induction of gaseous fuel along with air
2. Dual Fuel mode
3. Manifold Injection using injectors
4. Port Injection using injectors

**Table 1.Properties of gaseous fuel**

| Properties | Acetylene | Hydrogen | Diesel |
|---|---|---|---|
| Formula | $C_2H_2$ | $H_2$ | $C_8 – C_{20}$ |
| Density ($kg/m^3$) | 1.092 | 0.08 | 840 |

  

| | | | |
|---|---|---|---|
| Stoichiometric air fuel ratio, (kg/kg) | 11.82 | 34.3 | 14.5 |
| Molecular Weight (grams) | 24.06 | 2.016 | 170 |
| Auto ignition temperature (ºC) | 330 | 572 | 257 |
| Flammability Limits (Volume %) | 2.5 – 80 | 4 – 74.5 | 0.6 – 5.5 |
| Lower Calorific Value(kJ/kg) | 48,225 | 1,20,000 | 42,500 |
| Flame speed (m/s) | 6.097 | 3.5 | 0.3 |
| Ignition energy (mJ) | 0.019 | 0.02 | -------- |

## 7.Experimental Procedure

Gaseous fuel was supplied from a high-pressure cylinder (150 bar) to the engine at an outlet pressure of 2 bar. The pressure reduction was done by using a pressure regulator mounted on the high-pressure cylinder. Gaseous fuel was then passed through a flow control valve to adjust the flow rate of gas. from where it passed through the gas flow meter, which meters the flow of gas in terms of Standard Liters per Minute. The flow of gas was varied from 4 lpm, 5 lpm, and 6 lpm respectively. Gaseous fuel was then passed through flame arrestor used to suppress possible fire hazards in the system. These flame arrestors operate on the basic-principle that the flame gets quenched, if sufficient heat can be removed from the gas by the arrestors. It also acts a non-return valve. Then Gaseous fuel was allowed to pass through flame trap used to suppress the flash back if any into the intake manifold. The flame trap used here was a wet type flame trap.

### 7.1 SCHEMATIC OF THE EXPERIMENTAL SETUP

The schematic of the experimental setup was shown in figure .1

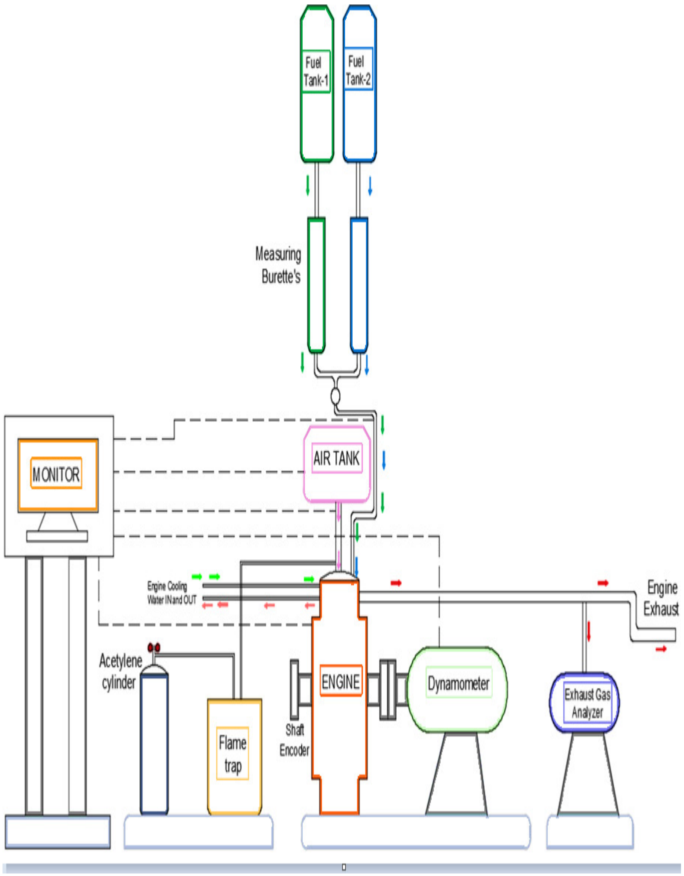


**Fig.1.Experimental setup**

## 8. Emissions and Exhaust Gas Temperature Measurement

The engine exhaust emissions like $NO_X$, Smoke, HC, CO and exhaust gas temperature were measured by using appropriate instruments.

### 8.1 Smoke intensity

Smoke intensity was measured using a Bosch smoke meter. It consists of a sampling pump and an evaluating unit. The exhaust gas by means of a spring operating plunger to be drawn by the sampling pump and released remotely by pneumatic operation of a diaphragm. The filter paper to be placed on the filter paper disc. The gas sample to be evaluated by means of a photocell reflector meter unit to give a precise assessment of the intensity of the spot. The intensity of the spot to be measured on a scale of 10 arbitrary units called Bosch smoke number.

#### 8.2 Measurements of NOx, HC and CO

HC, CO, NOx emissions were measured by QROTECH, QRO-401 exhaust gas analyzer. This analyzer to be configured to perform a measurement by applying Non dispersive infrared (NDIR) method for analyzing CO and HC and electrochemical method for analyzing NOx. In the NDIR analyzing method, a flashing lamp which flashes the infrared rays is attached at one end of the sample cell and at the other end, a detecting sensor is attached so that it can detect the component of a gas and then calculate the gas density. The electrochemical method measures the gas density by using the quantity of oxidation and reducing reaction of the gas. HC and NOx are to be measured in ppm and CO in % by volume.

### 9.Performance parameters

The various performance, emission, combustion characteristics can be analyzed after the induction of gaseous fuel in Compression ignition Engines are listed below.

a. BTE for Diesel and Gaseous fuel at full load

b. BSEC for Diesel and Gaseous fuel at full load

c. NO for Diesel and Gaseous fuel at full load

d. HC for Diesel and Gaseous fuel at full load

e. CO for Diesel and Gaseous fuel at full load

f. Smoke for Diesel and Gaseous fuel at full load

g. In cylinder Pressure for Diesel and Gaseous fuel at full load

### 9. CONCLUSIONS :

This paper depicts the implementation of the usage of Gaseous fuels such as Acetylene, Hydrogen in CI Engines with the safety concerns. Also, the various methods of inducting the gaseous fuels in the experimental Procedure and the Performance, Emission, Combustion characteristics were studied. Hence the gaseous fuels after analyzing all the chemical, material compatibility, physical and characteristics, structural and storage and handling methods, various production methods have to be carefully analysed and it can be inducted in Compression ignition engines

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