Acetylene Gas as an Alternative Fuel for Spark Ignition Engine

Jai Vardhan Srivastava[1] Harsh Vardhan Srivastava[2] Mohd. Shahid Khan[3]
[1,2,3]Department of Mechanical Engineering
[1]BBD Engineering College, Lucknow, U.P., India, 226028 [2]R.K.D.F. University, Bhopal, M.P., India, 462001 [3]AIET, Lucknow, U.P., India, 226002

Abstract— In the present scenario of energy resources most of the fuel used are fossil fuels and they are going to be exhaust very soon. The need of the present world is to search for some alternative resources. We have some choices like LPG, CNG, Hydrogen gas but due their drawbacks and lack of technology in some cases it is very complicated to use them. Acetylene is a very good fuel for running automobiles; this paper shows the mechanism with total setup for running IC engine by acetylene gas produced on board.

Key words: Alternative Fuel, Thermodynamic Approach, Comparison, Exhaust Analysis, Emission, POCP

I. Introduction

Presently world is facing difficulties due to the crisis of fuels, their increasing cost and environmental degradation caused by them. Internal combustion Engines use conventional hydrocarbon fuels and have dominated in many fields like transportation, agriculture and power generation which undesirably leads to pollutant like hydrocarbons (C_xH_y), oxides of sulphur (SO_x), oxides of carbon (CO_x) and particulates which are highly harmful to human health and are contributing in increasing the amount of green house gases and ultimately global warming[6].

Natural gas, Liquefied Petroleum Gas (LPG), Hydrogen, Acetylene, Producer gas, Alcohol and Vegetable oils are promising fuels for I.C. Engine. There has been a considerable effort made across the world to develop in alternative gaseous fuel from above mentioned fuels to replace conventional fuels by partial replacement or fully replacement. Many of the gaseous fuels obtained from renewable resources have a high self ignition temperature and hence are excellent for spark ignition engine.

The principal objective of this project include the mechanism and total setup for running the I.C. Engine by acetylene gas produced on board.

II. About Acetyle1ne

Acetylene is a colorless gas with garlic smell produced from calcium carbide (CaC_2), which is obtained from calcium carbonate ($CaCO_3$). Calcium Carbonate is heated in lime kiln at 825˚C which forms Calcium Oxide (lime) liberating Carbon Dioxide (CO_2) is then heated in electric furnace with coke to produce Calcium Carbide (CaC_2).

$$CaCO_3 \xrightarrow[\text{lime kiln}]{825\ C} CaO + CO_2 \quad \text{Electric Furnace}$$

Finally Calcium Carbide is hydrolyzed reducing acetylene.

Acetylene gas is colorless, highly combustible with high flame speed and fast energy released, it can be used as alternative fuel in I.C. Engine. It has a very wide flame ability range and minimum energy required for ignition on comparing with various other fuel properties, acetylene proved good to be used in I.C. Engine.

Physical and combustion Properties of Fuels	Acetylene	Hydrogen	Diesel
Fuel	C_2H_2	H_2	C_8-C_{20}
Density kg/m^3 (At 1 atm & 20^{0}C)	1.092	0.08	840
Auto ignition temperature	305	572	257
Stoichiometric air fuel ratio (kg/kg)	13.2	34.3	14.5
Flammability Limits (Volume%)	2.5-81	4-74.5	0.6-5.5
Flammability Limits (Equivalent ratio)	0.3-9.6	0.1-6.9	------
Lower Calorific Value (kj/kg)	48,225	1,20,,000	42,500
Lover Calorific Value (kj/m^3)	50,636	9600	------
Max. Deflagration speed (m/sec)	1.5	3.5	0.3
Ignition energy (MJ)	0.019	0.02	-----
Lover Heating Value of Stoichiometric Mixture (kj/kg)	3396	3399	2930

Table 1: Comparison with Other Fuels [9]

III. Overview of Project

A. Step 1

The first step involves the production of acetylene gas by reacting Calcium Carbide with water in the reaction cylinder

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

The acetylene gas so produced gets stored in the reaction cylinder and its pressure is measured by the pressure gauge provided at the top of cylinder

B. Step 2

After the production of acetylene gas, this gas goes to the primary condenser which is mounted on reaction cylinder and then to secondary condenser. Both the condenser remove the water content from the gas. The secondary condenser also consists of a valve which controls the forward flow of acetylene gas.

Fig. 1: Working project

The valve attached at the end of secondary condenser is kept closed to generate the pressured gas.

Fig. 2: Reaction Cylinder.

C. Step 3

The gas produced is controlled by the valve and pass through the sophisticated pipe to increase the pressure and goes to the skipper switch assembly which decide the selection of fuel i.e. either acetylene or petrol is selected.

D. Step 4

The acetylene gas goes to the vaporizer by the action of high vacuum of intake manifold, where most of the heat is absorbed in the fuel and there by the fuel vaporized close to the concentration of the oxygen it will combust with.

Fig. 3: Vaporizer

Fig. 4: Skipper Switch Assembly

E. Step 5

The highly concentrated acetylene gas from vaporizer is passed to the carburetor then from carburetor to engine for combustion.

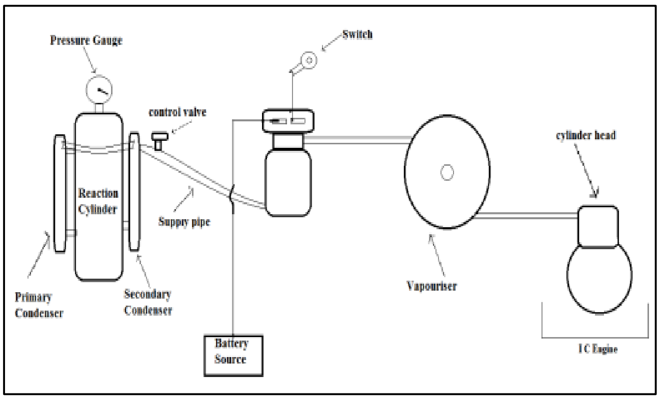

Fig. 5:

IV. THERMODYNAMIC EVALUATION OF PROJECT

A. Stiochiometric Air/Fuel Ratio Calculation

$C_aH_b + (a+b/4)(O_2+3.773N_2) \rightarrow aCO_2 + (b/2)(H_2O) +3.773(a+b/4)$

1) (A/F Ratio) C_2H_2

$$\frac{\left(1+\frac{y}{4}\right)(32+3.77X28.06)}{(12.011+1.008y)} = 13.28(y=1)$$

2) (A/F ratio) $C_8H_{14.96}$

$$\frac{\left(1+\frac{y}{4}\right)(32+3.773X25.06)}{(12.011+1.008y)} = 14.61\ (y=1.87)$$

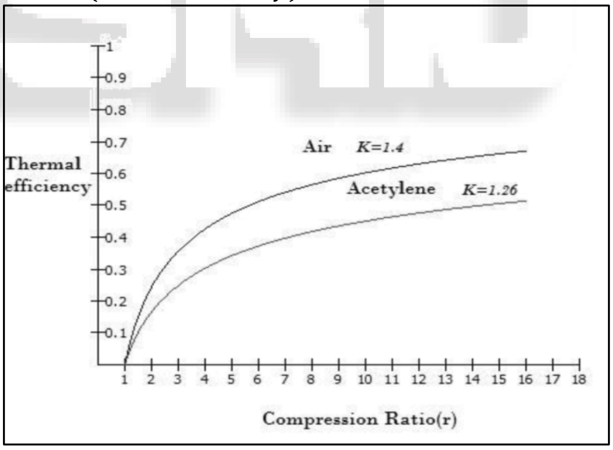

Fig. 5: Comparison of Thermal Efficiency by Adiabatic Constant

V. EXHAUST GAS COMPOSITION BY THERMODYNAMIC

A. Approach for Rich Mixture ($\varnothing$ = 1.2)

$C_8H_{14.96} + (11.74/\emptyset)(O_2+3.773N_2)\ aCO_2 + bH_2O + cCO + dH_2 + 44.295N_2$ (T=1700K)

$C_2H_2 + (12.5/\emptyset)(O_2+3.773N_2)\ aCO_2 + bH_2O + cCO + dH_2+9.4325N_2$

$Log_{10}K_p = 8.011 + 4.699 – 12.180 = 0.530$

Where,

K_p = 3.338 (Equilibrium constant) from JANAF table.

By balancing the no. of moles we get the following quadratic function,

2.38C2 - 36.701C + 105.830 = 0
So, C = 3.83
(a=4.16, b=7.406, c=3.84, d=0.074)C8H14.96
(a=1.27, b=0.896, c=0.73, d=0.104)C2H2

Gasoline ($C_8H_{14.96}$)		Acetylene (C_2H_2)	
CO_2	0.0695	CO_2	0.0804
H_2O	0.1239	H_2O	0.720
CO	0.0642	CO	0.058
H_2	0.00124	H_2	0.00836
N_2	0.7410	N_2	0.7586

Table 2: Exhaust Gas Composition per Unit Mole [6]

(Note that the carbon monoxide emission for gasoline is greater than that of acetylene)

VI. ENVIRONMENTAL ASPECTS

A. Total Emissions in Metric Tons

Molecular weight of acetylene = 26
No. of carbon atoms in acetylene = 2.
Molecular weight of CO2 = 44
No. of carbon atom in CO2 = 1.

Each mole of acetylene, under complete combustion, will create two moles of CO2 (i.e., each pound of acetylene combusted will produce 3.38 pounds of CO2 (2x44/26)).

Use the following conversion calculations to derive an emission factor for acetylene:

$$\frac{0.068lb}{1\ cubic\ feet\ C_2H_2} \times \frac{453.6g}{1\ lb} = \frac{30.845g}{1\ cubic\ feet\ of\ C_2H_2}$$

$$\frac{30.845g}{1\ cubic\ feet\ C_2H_2} \times \frac{1}{\frac{26.04}{1} molC_2H_2} = \frac{1.185\ mol\ C_2H_2}{1\ cubic\ feet\ of C_2H_2}$$

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$$\frac{1.185\ mol\ C_2H_2}{1\ cubic\ feet\ C_2H_2} \times \frac{2\ mol\ CO_2}{1\ mol\ C_2H_2} = \frac{2.370\ molCO_2}{1\ cubic\ feet\ of\ C_2H_2}$$

$$\frac{2.370\ molCO_2}{1\ cubic\ feet\ C_2H_2} \times \frac{44.01}{1\ mol\ CO_2} = \frac{104.304g\ CO_2}{1\ cubic\ feet\ of\ C_2H_2}$$

$$\frac{104.304g\ CO_2}{1\ cubic\ feet\ of\ C_2H_2} \times \frac{1\ metric\ tone}{10^6}$$

$$= \frac{1.403 \times 10^{-4} m.tonCO_2}{1\ cubic\ feet\ of\ C_2H_2}$$

Acetylene consumed (cubic feet) ×Acetylene Emission Factor = Total emissions (metric tons CO2)

The result obtained from above calculation shows that the amount of CO2 emitted is fairly minimum and other emissions like NO_x, SO_x are highly negligible compared to CO_2. This indicates that acetylene can be relatively more environmental friendly than gasoline.

B. Ozone Layer Depletion (Photochemical Ozone Creation Potential POCP)

Ozone plays protective role in the stratosphere but at ground-level ozone is a dangerous gas. Photochemical ozone production in the troposphere, also known as summer smog, is suspected to damage vegetation. A high concentration of ozone at ground level is toxic to humans.

Complex chemical reactions occurring between oxides of nitrogen and hydrocarbon in the presence of radiation from sun produce aggressive reaction products, one of which is ozone. Nitrogen oxides alone do not cause high ozone concentration levels. Here are some of the comparisons of POPC between several compounds.

VOC	POCP
Ethane C_2H_6	8.8
Propane C_3H_8	18.3
n- Butane n- C_4H_{10}	36.3
n- Propane C_5H_{12}	36.6
2,2- Dimthylpropane, $C(CH_3)_4$	20.3
n- Hexane, $CH_3(CH_2)_4$ CH_3	45.6
n- Octane, $CH_3(CH_2)_6$ CH_3	40.1
Ethylene, CH_2- CH_2	100.0
Propane, CH_3 CH- CH_2	105.4
Trans-2-butane, CH_3 CH= CH CH_3	110.7
Acetylene CH=CH	9.9
Formaldehyde, HCHO	47.1
Acetaldehyde, CH_3 CHO	55.0
Acetone, CH_3 CO CH_3	7.5
Butanone, $C_2H_5COCH_3$	35.3
Methanol, CH_3 OH	16.5
Ethanol, C_2H_5 OH	39.7
Dimethyl ether, CH_3OCH_3	19.8
Benzene, C_6H_6	20.3
Toluene, C_6H_5 CH_3	51.2

Table 4: POPC Comparison of Different Compounds [6]

Note that acetylene has very low POPC that implies it has low reactivity towards OH- radical.

Depending upon the structure of fuel the total emission varies to a great extent. This variation is due to the diffusion and reactivity of fuel. The fuel molecules diffuse from the boundary layer near the cylinder wall into the hot core gas causing partial oxidation. This fuel may be a significant source of burn up hydrocarbon species exiting the cervices during the expansion stroke. Thus, higher molecular weight fuels, which diffuse more slowly, tend to exhibit higher emission.

VII. CONCLUSION

This project includes the total mechanism and setup for using acetylene as an alternative fuel for I.C. engine. As comparable to petrol and gasoline, acetylene can be produced easily and is very much cost effective. I.C. engine using acetylene as fuel emits less amount of CO2 comparable to fossil fuels thus its use can be very beneficial. Acetylene can also replace L.P.G. with similar minor manipulation in the engine.

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