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Challenges to use Acetylene Gas as an Alternative Fuel for I. C. Engine

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Abstract: *Here, an attempt has been made to critically review research papers on use of acetylene gas in IC engine to determine the major challenges and effects on engine performance. It is well known fact that our petroleum resources will depleted in near future. There are many characteristics of acetylene gas which are match with our traditional petroleum fuels. The use of acetylene in IC engine will help to control pollution and reduce the dependency on petroleum. Studies reveal that the acetylene is very high flammable and explosive in nature. The major challenge to use of acetylene gas in engine will create detonation due to its wide flammability and low octane number. Many of the researcher use acetylene with another fuel to better performance of engine and preventing knocking. The experimental studies shows that the use of acetylene gas with alcohol and diethyl ether gives the better performance of engine. To controlling air fuel ratio and compression ratio also the challenge while use the acetylene gas in IC engine to get better performance. Safety is also the major factor to run the IC Engine with acetylene gas. To avoid any explosion the controlling the fuel delivery pressure at proper level is also be challenged.*

I. Introduction:

Our present fuel resources are not going to be around forever and with the ever increasing consumption their extinction is nearly unavoidable. Also our fuel resources which are mostly made up of fossil fuels are not renewable in nature.
Currently around the world the consumption of fossil fuels is 100,000 times faster than their natural production. According to an estimate the demand for these fuels will suddenly outstrip their availability in a matter of centuries-or less. Also the combustion of fossil fuels emit harmful gases. This harmful gas when released into the atmosphere makes a huge contribution to the greenhouse effect.
Thus there is a need of alternative fuel which reduce the dependency on fossil fuel and control the pollution. The studies shows that the gaseous fuels like acetylene, hydrogen and natural gas are good alternate fuel to reduce pollution. It is found that the properties of the acetylene are match with the present fuels. The acetylene gas is produce from calcium carbide $CaCO_2$, which is obtained from calcium carbonate $CaCO_3$. When the calcium carbonate is heated at temperature 825°C in lime kiln it forms calcium oxide and CO_2, then calcium oxide is heated with coke in furnace which give calcium carbide and finally it hydrolyzed producing Acetylene [1].
The use of acetylene in IC engine produced detonation due to its wide flammability and low octane number. it is impossible to run an internal combustion engine on acetylene without controlling the detonation phenomena. Thus it is necessary to use the acetylene with another fuel, the study shows that the alcohol is good fuel to control detonation phenomena [6]. The another concern is to determine the antiknock property of acetylene. It was found that acetylene have octane number 50 at critical compression ratio of 3.85 at 600 rev/min, wide - open throttle. When the engine speed was increased the quality of octane number was decreased, it is less than 45 at 2000 rev/min [5].The comparison of properties of acetylene with other fuels are shown below[3].

Table 1 Comparison of acetylene gas with other fuels

Properties	Acetylene	Hydrogen	CNG	Petrol
Composition	C_2H_2	H_2	Ch_4:86.490%	C_8H_{18}
Density kg/m3 (At 1 atm & 20℃)	1.092	0.08	0.72	800
Auto ignition temp(℃)	305	572	450	246
Stiochiometric air fuel ratio (kg/kg)	13.2	34.3	17.3	14.7
Flammability Limits (Volume %)	2.5-81	4-74.5	5.3-15	1.2-8
Lower Calorific Value (kj/kg)	48225	12000	45800	44500

Ignition energy (MJ)	0.019	0.02	-------------	
Lower Calorific Value (kj/m3)	50636	9600	-------------	
Ignition energy (MJ)	0.019	0.02	-------------	
Flammability Limits (Equivalent ratio)	0.3-9.6	0.1-6.9	0.4-1.6	

II. LITERATURE REVIEW

Prabin K. Sharma et al. Studied shows that, They stored the acetylene gas in storage tank , supplied to the carburetor and then gasoline is added as secondary fuel with acetylene gas in very few amount about 10 to 15% to avoid knocking. Also, They illustrate that introducing alcohol as secondary fuel helps to reduce the adiabatic flame temperature in the combustion process which prevent auto ignition and knocking. The result obtained from the calculation illustrates that the amount of CO2 emitted is fairly minimum and other emissions like NOx, Sox are highly negligible compared to CO2. This indicates that acetylene can be relatively more environmental friendly than gasoline. There are more modification required in engine configuration to run the engine with acetylene and alcohol. The major challenge was found that to control the detonation effect and certain modification required for introduce acetylene gas and safety issue during the handling of acetylene gas [1].

S. Brusca et al. Conducted theoretically and experimentally analysis the Internal combustion engine by using acetylene and alcohol as fuel. They were used 8kw spark ignition engine with two injectors, one for alcohol and another one for acetylene, the electronic control unit manage the injection control system. Genetic algorithms and neural networks methods were used to mapping the engine parameters.
To run the engine with alcohol and acetylene following modifications were done.

- Substitute the gasoline tank with alcohol suitable tank.
- Secured acetylene suitable tank was consider.
- Modified the intake pipe for install the fuel injectors.
- To control injection and ignition ECU was introduced
- Exhaust pipe was modified for installation of lamda sensor.

The comparison of two analyzed engine one for gasoline (original) and another for acetylene – alcohol (new) results shows that, engine running on acetylene and alcohol has about 25 % reduction in engine performance because of the reduced global low heating value and likely because of the use of a combustion chamber optimized for gasoline combustion. The analysis show that, the brake specific fuel consumption of acetylene-alcohol is lower than gasoline brake specific fuel consumption in almost all engine speed analysed. There is slight increased in acetylene-alcohol brake specific fuel consumption at maximum engine speed due to different lower heating value of acetylene alcohol mixture. It is observed that there was a strong reduction in CO emission occurs while engine running on acetylene alcohol instead of gasoline and also HC and NOX emission also decreased. This effect are due to lower combustion temperature due to lower heating value of fuel and refrigerant effect of alcohol during combustion tail. The major challenge was found that to modified the engine for alcohol –acetylene mode and mapping and optimization of engine parameters[6].

Kumar*et al. Conducted experiment to study the performance characteristics of Direct injection petrol engine in dual fuel mode by aspirating Acetylene gas in the inlet manifold, with petrol- diethyl ether blends (DEE) as an ignition source. They were supplied the fixed quantity of acetylene gas and blend the petrol with diethyl ether(DEE10, DEE20and DEE30) was taken and determine the results at various loads. From the results it has been concluded that the blending ratio of DEE20 gives better performance.
They were use following set up for their experiment,
1.Air operation flow meter ,2. Petrol fuel tank ,3. Petrol engine 4. Acetylene generator, 5. Flame trap , 6. Flow control valve 7. Gas flow meter , 8. Intake manifold , 9. Dynamometer. 10. Control panel , 11.OsSIlloscope, *12.Gas* analyser.
The study shows that the brake thermal efficiency is found to be 11.23% lower, when compared with neat petrol fuel of 28.84% efficiency at full load. Acetylene gas have wide flammability limit and high combustion rate thus at high loads, the brake thermal efficiency falls because of high diffusion rate and faster energy release. The Experimental result shows that exhaust gas temperature at full load, reaches 368^{o}C in acetylene induction technique and 444^{o}C in the case of base line petrol operation. Acetylene induction decreased the exhaust gas temperature at all loads, indicating the advancement of energy release in the cycle and higher flame speed. It is observed that the NO*x* emission is increased by 17% when compared to

baseline petrol operation. When acetylene is inducted, increase in NO*x* may be attributed to the increased peak cycle temperature level because of faster energy release, which is confirmed by increased peak cycle pressure. It is noticed that the smoke level is reduced by 14% in induction technique at full load when compared to baseline petrol operation. This may be attributed to the fact that combustion of acetylene-petrol fuel is faster, contributing to complete combustion, and is also due to triple bond in acetylene which is unstable. The CO emissions are lower compared to the base line petrol operation. The maximum is 0.01% by volume in induction technique followed by base line petrol of 0.02% at full load. The CO emissions are lower due to the complete burning of the fuel, and is also due to the reduction in the overall C/H ratio of total fuel inducted into the engine. The CO_2 emissions are lower compared to the base line petrol, the minimum being 8.7% by volume at full load in acetylene induction technique followed by 9.0% by volume in baseline petrol operation. The peak pressure is about 72.1 bar at maximum power with base line petrol operation. Peak pressure is further increased in dual fuel operation with acetylene induction at maximum load. In dual fuel engine, the trend of increase in peak pressure is due to increased ignition delay and rapidity of combustion. There is an increase to about 3. bar when acetylene is inducted. The peak pressure for acetylene inducted dual fuel engine is advanced by 5°CA compared to peak pressure of petrol at full load. The advance in peak pressure for acetylene combustion is perhaps due to instantaneous combustion of acetylene as compared to petrol. The rate of pressure rise is also high for acetylene operated dual fuel engine, compared to petrol operated engine due to instantaneous combustion of acetylene fuel. The heat release rate for acetylene aspiration shows distinct characteristics of explosive, premixed type combustion followed by a brief second phase dip in burning rate and then a rapid increase during the third phase of combustion of the gas mostly diffusion type of combustion[2].

Mehmet İlhan *et al. study investigated the effect of adding of acetylene (as 500 g/h and 1,000 g/h) to gasoline on emissions and performance of an SI engine at 1,500 rpm engine speed and two different engine loads (25% and 50%). When λ is between 0.9 and 1.3, the addition of acetylene to gasoline leads to a decline in the thermal efficiency. As acetylene has lower octane number, knocking can occur in the cylinder and so ignition in the cylinder is carried out around top dead center. This leads to a reduction in peak pressure and thermal efficiency. Increasing with excess air ratio, getting away from the knock zone, values of high excess air ratio allow higher ignition timing and the increasing of thermal efficiency values has been observed with lambda values are increased. It has been observed that gasoline-acetylene mixtures can flame without any problem in wider range values of excess air ratio than gasoline due to acetylene has a wide range of flammability limits. The effect of acetylene on the engine performance declines when the engine load is increased. Due to the high flame speed of acetylene, it is determined that the addition of acetylene to the gasoline shortens the combustion durations and also limits the negative effect of the increase in the lambda on the burning time. The increasing of acetylene to gasoline causes a slight increase in CO emissions under rich and stoichiometric mixing conditions. But, the adding of acetylene generally causes a partial decrease in the CO emissions above λ=1.1. The acetylene added to gasoline significantly reduces the emissions of UHC due to acetylene has a higher flame speed and short quenching distance. The addition of acetylene caused an increase in NO_X emissions at between =0.9 and =1.3. However, acetylene decreased NOx emissions at high excess air ratios[4].

David l. hilden and russell f. stebar conducted experiment on the test engine had a bore of 82.6 mm, a stroke of 114.3 mm and a displacement of 0-611. The engine was equipped with a Research Method camshaft and a shrouded intake valve. The performance and emission characteristics of acetylene were determined using a Cooperative Fuel Research CFR), split-head, variable compression ratio, spark ignition engine. The result show that acetylene-fuelled engines cannot be operated over a wide range of conditions because the compression ratio and rich mixture limits for acetylene are much more restrictive than those for gasoline. Acetylene's poor octane quality is believed to be the dominant cause of its severely limited operating capability at both richer mixtures and at higher compression ratios. The study shows that the indicated power with acetylene decreased with leaner mixtures at a given compression ratio and increased with increasing compression ratio at a given stoichiometry. The highest knock-free power level with acetylene (2.5 kW at 6-0 compression ratio) was 94 per cent of that obtained with the reference gasoline at its lean limit. The maximum power, however, was only 72 per cent of the peak value obtained with gasoline[5].

T.Lakshamanan et al conducted experiments on a single cylinder, direct injection, and compression ignition engine run on dual fuel mode with diesel as an injected primary fuel and acetylene inducted as secondary gaseous fuel to obtain data on engine performance and exhaust emissions. A single cylinder four stroke air cooled naturally aspirated direct injection diesel engine developing 4.4 kW at 1500 rpm, fueled with diesel fuel was utilized for acetylene dual fuel operation. It is observed that the brake thermal efficiency in induction technique is found to be 11.23% lower, when compared with neat diesel fuel of 28.84% efficiency at full load. it may be noted that in the dual-fuel engines, the thermal efficiency decreases at low loads and in the cycle and higher flame speed increases above the base line at full load operation with addition of inducted fuels like LPG, CNG etc. it is conclude that Brake thermal efficiency in dual fuel mode is lower than diesel operation at full load, as a result of continuous induction of acetylene in the intake. There result shows that the acetylene operated engine have a slight decrease in thermal efficiency, when compared to baseline diesel operation. Exhaust temperature, HC, CO, CO_2 and smoke emissions were less than baseline diesel operation[7].

T.Lakshamanan et al studied the performance and emissions characteristics of acetylene fuelled engine at different flow rates by using timed manifold injection technique and introduce EGR to reduce NOx emission. The studies reveled that the exhaust gas temperature decreased in the case of dual fuel operation of acetylene without EGR and with EGR. At rated load NOx value for acetylene, manifold injection without EGR is 9.68 g/kWh whereas with 20% EGR NOx value is 7.60 g/kWh. The reduction in NOx is due to the reduction in peak combustion temperature because of the presence of inert gas in EGR. With the application of EGR, due to lower excess oxygen available for combustion it results in incomplete combustion leading to slight increase in CO and HC emission level. CO2 emission increases with EGR application in the inlet air due to the presence of CO2 in the exhaust. The experimental investigation on a single cylinder diesel engine with acetylene diesel in dual fuel mode in TMI technique with cooled EGR resulted in reduction in NOx level, with slight increase in smoke level with smoother operation of the engine at the penalty of efficiency. Without any sacrifice in the efficiency, low EGR percentage is preferred for NOx reduction in acetylene diesel operation[8].

CONCLUSION

From the review of different research papers, it is conclude that it is necessary to control detonation effect when IC engine is running on acetylene gas. The use of alcohol as secondary fuel help to control the detonation effect but engine running on acetylene and alcohol has about 25 % reduction in engine performance because of the reduced global low heating value and likely because of the use of a combustion chamber optimized for gasoline combustion. The another study on petrol engine in dual fuel mode by aspirating Acetylene gas in the inlet manifold, with petrol- diethyl ether blends as an ignition source help to reduces smoke and exhaust temperature. The timed manifold injection (TMI) is a good technique to eliminate pre ignition and knocking which is controlled electronically to precisely monitor the induction of fuel. The use of cooled Exhaust gas recirculation system help to reduce emissions from acetylene diesel engine. It is observed that there are more research work required to increase the performance of acetylene operated IC engine and safety parameters required while handling and testing acetylene.

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