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Experiment Investigations on CNG Injection System Performance in Single Cylinder Four Stroke SI Engine – Review Paper

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Abstract - *Compressed Natural Gas (CNG) is regarded as one of the most promising alternative fuels, and may be the cleanest fuel for the spark ignited (SI) engine. Now a day's CNG kit for SI engine contains various types of injection systems with ECU (Electronic control unit). So this research will deal with single point injection system. Here experimental investigations on fuel injection using CNG in Single Cylinder four Stroke SI Engine will be carried out. Desired pressure (4 to 8 bar) will be injected in the intake manifold using CNG injector to check the performance. Experiments will be done on different speed and load condition to check Engine performance. This research will also be helpful to improve engine economy, performance and efficiency.*

Key Words: Compressed natural gas, alternative fuel, engine development, performance; emission.

1. INTRODUCTION

It is well known that the fossil-fuel reserves in the world are diminishing at an alarming rate and a lack of crude oil is expected at the early decades of this century. Gasoline and diesel fuel becomes scarce and most expensive. Alternative fuel becomes more conventional fuel in the coming decades for internal-combustion engines. Nowadays, the alternative fuel has been growing due to concerns that the reserves of fossil fuel all over the area are limited. Furthermore the world energy crisis made the fossil-fuel price increases.

1.1 Significance of Alternative Fuels

All these years there have always been some IC engines fuelled with non gasoline or diesel oil fuels. However, there numbers have been relatively small .Because of the high cost of petroleum products; some developing countries are trying to use alternate fuels for their vehicles. Another reason motivating the development of alternate fuels for the IC engine is concern over the emission problem of gasoline engines. Combined with other air-polluting systems, the large number of automobiles is a major contributor to the air quality problem of the world. Quite a lot of improvements have been made in reducing emissions given off by an automobile engine. If a 35% improvement made over a period of years, it is to be noted that during the same time the lifting the improvement. Lot of efforts has gone into for achieving the net improvement in cleaning up automobile exhaust. However, more improvements are needed to bring down the ever-increasing air pollution due to automobile population one more reason for alternate fuel development is the fact that large. One more reason for alternate fuel development is the fact that large percentage of crude oil must be imported from other countries which control the larger oil fields. As of now many alternate fuels have been used in limited quantities in automobiles. Quite often, fleet vehicles have been used for testing. This allows for comparison with similar gasoline- fuelled vehicles, and simplifies fuelling of these vehicles.

1.2 Generation of Natural Gas

Natural Gas (NG) has been found in various locations in oil and gas bearing sands strata located at different depths below the earth surface. NG is a gaseous form of NG was compressed. It has been recognized as one of the promising alternative fuels due to its significant benefits compared to gasoline fuel and diesel fuel. These include reduced fuel cost, cleaner exhaust gas emissions and higher octane number. Therefore, the numbers of engine vehicles powered by NG were growing rapidly. NG is safer than gasoline in many respects. The ignition temperature of NG is higher than gasoline fuel and diesel fuel. Additionally, NG lighter than air and dissipate upward rapidly. Gasoline fuel and diesel fuel will pool on the ground, increasing the risk of fire. NG is nontoxic and will not contaminate groundwater if failed. Advanced NG engines undertake significant advantages over the conventional gasoline engine and diesel engine. NG is a commonly available type of fossil energy. However, the investigation of applying NG as an alternative fuel in engines will be a beneficial activity, because the liquid fossil fuels will be finished and will become scarce and expensive. NG has some advantages compared to gasoline and diesel from the environmental perspective.

1.3 What is Compressed Natural Gas?

Compressed natural gas (CNG) is a clean-burning alternative to gasoline or diesel used in transportation. Made of predominantly methane (CH_4), natural gas is the most commonly used alternative vehicle fuel in the United States.1 It is drawn from wells or extracted during crude oil production. While some petroleum is used in the production of natural gas, using it as a transportation fuel reduces petroleum consumption by more than 90% compared to gasoline. In transportation, natural gas is used either as CNG or as liquefied natural gas (LNG). Benefits of this fuel include cost savings, reduced emissions, ease of vehicle maintenance, and increased energy security.

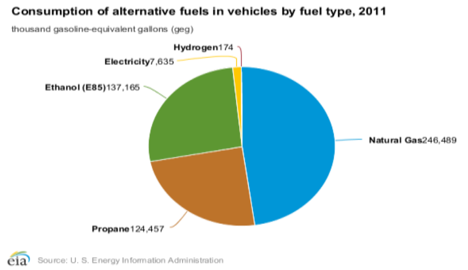

Fig-1: Natural gas is a popular choice for use in vehicles in the United States

Because natural gas has a lower energy density than liquid petroleum fuels, it is either compressed or liquefied to store more energy for increased vehicle range. Therefore, to use natural gas, vehicles must have a CNG- or LNG-specific fuel storage and delivery system installed. The installation can be done on a vehicle after it has been manufactured (i.e., CNG aftermarket retrofit) or at the vehicle factory as part of its original equipment. In the medium and heavy duty market, there are engine options that are designed to run exclusively on natural gas, as well as conversion options. In the light duty market, there are a few 'direct from the manufacturer' CNG options available. There is also a gaseous prep package option for the standard gasoline engine, which costs around $300 and includes hardened valves and valve seats. It is recommended that engines that will use natural gas have hardened valves and valve seats, because as a dry fuel, natural gas does not have the cooling effect and lubricity of liquid injected petroleum fuels. A "prepped" vehicle is then ready to be sent to a qualified system retrofitter to be up-fitted with a CNG system, with no engine modifications required and no impact on the manufacturer's power train warranty.

1.4 Demands for natural gas as a transportation fuel

Natural gas is becoming one of the most important resources of energy and currently shares 23% of world primary consumption. As reported by Cedigaz, the world's proved natural gas reserves are 7080.3 TCF as of January 1, 2014, which correlates to over 60-year supply at current annual consumption levels of 118.20 TCF. Fig.2 illustrates the global primary energy demand by fuel type from 1980 to 2035. It can be observed that natural gas will surpass coal before 2030 and will cover a 25% total energy demand in 2035. An IEO2014 projection of future energy demands shows that natural gas is the fastest- growing primary energy source in the future and its consumption is fore casted to be double between 2020 and2040. The report projected that growing production of natural gas from tight shale reservoirs will keep the prices of natural gas to customers under the price level of 2005–2008 through 2038. This hassled to a growing interest to use natural gas as a transportation fuel. The current annual consumption of natural gas as transportation fuel is 1.205 TCF, only accounts for 1.01% of total global demand for natural gas.

1.5 MERITS OF GASEOUS FUELS OVER LIQUID FUEL

- Gaseous fuels burn very clean
- They burn without any shoot, or smoke and ashes.
- Easy to burn – No atomization
- Excellent mixing
- No problems with erosion or corrosion
- The gas is easy to clean. E.g. if sulphur is present, it may be easily removed prior to Combustion

1.6 Fuel & infrastructure providers

Many fleets using natural gas depend on these publicly available stations for their operation. Much like a typical gasoline or diesel station, the driver pulls up to the dispenser and uses a credit card or fuel card to purchase fuel. Filling the vehicle's tank is comparable to filling with a petroleum fuel. No prior scheduling is required, although some stations are only open during regular business hours.

One advantage of using publicly available stations is cost savings. The fleet does not need to install and maintain its own dispensing equipment. On the other hand, the fleet may be inconvenienced if the dispenser goes down for service, if there is a high demand and wait time, or if there are other accessibility issues. Some fleet managers negotiate a bulk price for fuel when they operate their own stations, but are unable to do so when using a public station.

Fig- 2: Public Stations

1.7 Natural gas composition

Table-1: CNG Composition

Composition	Formula	Volume Fraction (%)
Methane	CH4	91.82 - 94.39
Ethane	C2H6	2.91 - 4.66
Propane	C3H8	0.57 - 1.13
Iso-Butane	i-C4H10	0.11 – 0.21
N-Butane	n-C4H10	0.15 – 0.29
Iso-Pentane	i-C5H12	0.02 – 0.1
N-pentane	n-C5H12	0.02 – 0.08
Nitrogen	N2	0.96 – 4.46
Carbon Dioxide	CO2	0.26 – 0.81
Hexane	C6+C6H14	0.01 – 0.17
Oxygen	O2	0.01
Carbon Monoxide	Co	< 0.01

1.8 Properties of CNG and gasoline

Table-1: Properties of CNG and gasoline

Properties	CNG	Gasoline
Octane number	120-130	85-95
Molar mass (kg/mol)	17.3	109
Stoichemetric (A/F)s mass	17.2	14.7
Stoichemetricmixture density(kg/m3)	1.25	1.42
L.H.V. (MJ/kg)	47.5	43.5
L.H.V. of stoichemetric mixture (MJ/kg)	2.62	2.85
Combustion Energy(MJ/m3)	24.6	42.7
Flammability limit in air (vol% in air)	4.3-15.2	1.4-7.6
Flame propagation speed (m/s)	0.41	0.5
Adiabatic Flame Temp.(1C)	1890	2150
Auto-ignition Temp.(1C)	540	258

1.9 Injection methods of natural gas engine

There are four methods to inject the NG into the engine cylinder. First type is gas mixer / carburettor injection, second type is the single point injection, third type is multi point injection and fourth type is direct injection.

The existing metering and mixing of the fuel may be accomplished using either a mechanical gaseous fuel mixer or carburetor, or an electronically controlled gaseous fuel metering system.

This approach strives to achieve a homogeneous mixture of air and fuel before the air flow splits in the intake manifold. This injection option can be increases emissions and the possibility of knock phenomena.

Single point injection is use gaseous fuel injector to mix the gaseous fuel with the intake air in the manifold at one location for all cylinders of the engine. In this case, fuel is injected in a single location much like a gas mixer or carburetor.

Single point electronic injection offers the advantage of more precise control of the amount of gaseous fuel entering the intake charge of the engine as well as the economy of using a minimum number of injectors.

Multi point injection (MPI) is to inject the fuel into the each cylinder via intake port before intake valve. This system uses one or more fuel injectors for each cylinder intake port of an engine and allows the designer to remove the fuel supply from the air supply area of the intake manifold.

Direct injection is to inject the gaseous fuel directly into each combustion chamber of the engine.

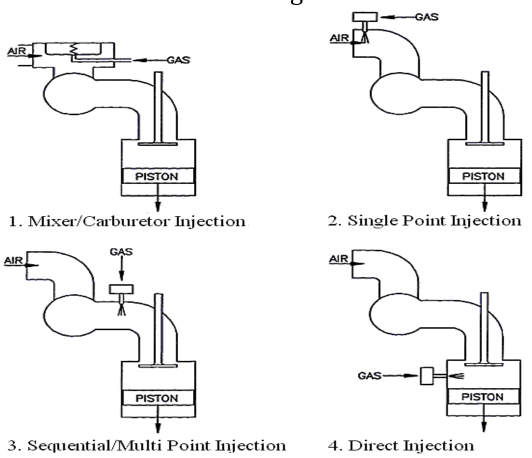

Fig-3: Injection Methods of Natural Gas Engine [Semin, Rosli Abu Bakar et all (2008)]

1.10 CNG engine emissions

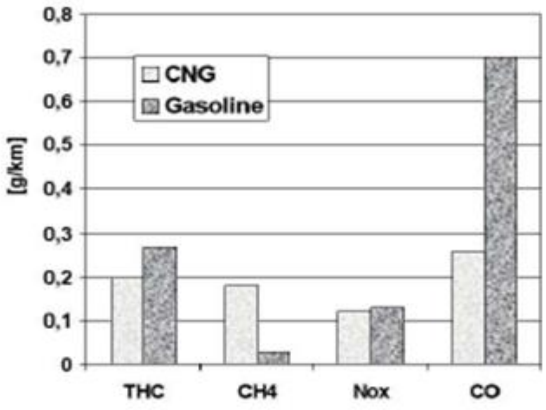

Fig-4: CNG Engine Emissions Result [Semin, Rosli Abu Bakar (2008)]

2. LITERATURE SURVEY

Muhammad Imran Khan et all. (2015) Shows "Technical overview of compressed natural gas (CNG) as a transportation fuel"

This paper presents the worldwide background, prospects and challenges of natural gas fuel and natural gas fuelled vehicles along with environmental and economic aspects of compressed natural gas as a transformation fuel. Technical aspects of compressed natural gas properties, storage, safety problems and its effect on engine performance, efficiency, emissions and barriers to natural gas vehicles adaptation are discussed in detail. The main indicators selected for the comparative assessment of natural gas as vehicular fuel are: economic, emission performance and safety aspect. The results showed that CNG has several advantages over both diesel and gasoline fuel, including considerable emission and cost reductions.[1]

Sangeeta, Sudheshna Moka et all. (2014) Shows "Alternative fuels: An overview of current trends and scope for future"

This paper presented the concern over rapid depletion of fossil fuels has prompted the search for alternative fuels having efficiencies similar to those found for the conventional fuels being used today. The properties of these fuels and their performance as a fuel are discussed in detail. Vegetable oils present a very promising scenario of functioning as alternatives to fossil fuels. Use of biodiesel in a conventional diesel engine results in a substantial reduction in unburned hydrocarbons, carbon monoxide, particulate matter, and nitrogen oxides. Different alternative fuels have been compared with the conventional fuels and clearly the consumption of the latter can be significantly decreased by the use the blended fuels. In order to successfully compete with conventional fuels, these alternative fuel show ever need to be improved in terms of their properties, production efficiency, and end-use suitability .Optimistically speaking, the magnitude of research efforts being put in this area should soon make the fossil fuels a thing of the past at least in the transportation sector, and consequently ensure that the future generations get a clean and green environment. Remaining petroleum may then better serve as a raw material for medicines, and thus as a boon for mankind. [4]

Yang Wang et all.(2016) Shows "Emission factors of air pollutants from CNG-gasoline bi-fuel vehicles: Part I. Black carbon"

In this paper, compressed natural gas (CNG) is considered to be a "cleaner" fuel compared to other fossil fuels. Therefore, it is used as an alternative fuel in motor vehicles to reduce emissions of air pollutants in transportation. In this study, a fleet of bi-fuel vehicles was selected to measure the emissions of black carbon (BC), carbon monoxide (CO), hydrocarbon (HC) and nitrogen oxide (NOx) for driving in CNG mode and gasoline mode respectively under the same set of constant speeds and accelerations. Comparison of emission factors (EFs) for the vehicles burning CNG and gasoline are discussed. Our results show that burning CNG will lead to 54%–83% reduction in BC emissions per kilometre, depending on actual driving conditions. These comparisons show that CNG is a cleaner fuel than gasoline for motor vehicles in terms of BC emissions and provide a viable option for reducing BC emissions cause by transportation. [8]

Mirko Baratta et all. (2014) Shows "Fluid-dynamic and numerical aspects in the simulation of direct CNG injection in spark-ignition engines"

The aim of the paper is to optimize the numerical simulation strategy for direct gas injection, in view of its application to internal combustion (IC) engines. In the first part of the paper, the widely studied case of a two-dimensional compressible flow is examined, and the main guidelines for the development of an effective numerical model for compressed natural gas (CNG) direct injection simulation are given, with specific reference to IC engines. A careful grid-independence study has been carried out in both the first and second part of the paper, and the influence of the spatial discretization of the convective fluxes has been discussed as well.

The analyses have shown that a resolution of 40 cells in the nozzle height should be adopted to describe the typical phenomena that characterize an under expanded free jet, unless a second order scheme can be implemented. As for the direct injection engine model, 16 cells across the nozzle lift represent a good compromise between accuracy and reliability of the results and the required computational time. The model has been validated with the support of experimental PLIF images in an optical-access engine, and has shown overall good accuracy and reliability, thus suggesting it is suitable for mixture formation analysis.[10]

Mirko Baratta et all.(2015) Shows "Modelling aspects of a CNG injection system to predict its behaviour under steady state conditions and throughout driving cycle simulations"

The present paper aims at developing a thorough model of the injection system with specific attention to the one component which significantly contributes to fully defining its dynamic response, i.e. the pressure reducing valve. The pressure reducer is made up of various elements that retain diverse weights on the valve behaviour and should consequently be differently addressed to. A refined model of the pressure reducer has hence been proposed and the model has been calibrated, tested and run under various operating conditions so as to assess for the set-up validity.

Finally, the model has been run in a predictive mode so as to inquiry into the response of the system to fast transient operations, both in terms of speed and load. The model outputs have highlighted mismatches between the ECU target mass and the actually injected one and have hinted at the need for dedicated and refined control strategies capable of preventing anomalies in the mixture formation and hence in the engine functioning.[11]

Mingi Choi et all.(2015) Shows 'Numerical and experimental study of gaseous fuel injection for CNG direct injection"

This paper describes numerical and experimental studies of gaseous fuel injection for CNG direct injection. To simulate the CNG direct injection, the injection sub-model was updated to include gaseous fuel injection methodology. The gaseous fuel injection methodology, which is similar to a liquid injection model, can be used in the KIVA-3V Release 2 code with some modifications. In addition, this model can be used to simulate gaseous fuel injection using a coarse mesh, which saves calculation time.

A PLIF (planar laser induced fluorescence) method was used for the gaseous fuel injection experiments. Acetone was selected as a tracer and post-image processing was performed using MATLAB code. In this study, the simulation results of CNG injection were compared to experimental data. Through comparison of the spray tip penetration results to experimental measurements, the gaseous fuel injection model produced reliable results for gas fuel direct injection. [12]

Mingi Choi et all.(2016) Shows "Modelling of the fuel injection and combustion process in a CNG direct injection engine"

This paper describes a methodology to model the gaseous fuel injection process in a compressed natural gas (CNG) direct injection (DI) engine. Simulations were conducted using KIVA-3V Release 2 code by modifying the liquid fuel injection model to function as a gaseous fuel injection model. This model simulated gaseous fuel injection using a coarse mesh.

The experiments were performed for gas-jet visualization using the planar laser induced fluorescence (PLIF) method. The compressed nitrogen was used instead of CNG fuel for safety reasons. The gaseous fuel injection model was validated by comparing the simulation and experimental results. The experimental results of the in-cylinder pressure were compared to calculated results for validation of the combustion model. The fuel injection and combustion process were simulated using a three-dimensional engine mesh with four valves from intake valve open (IVO) to exhaust valve open (EVO). The simulation results show that the fuel mass decreased slowly at the 270 BTDC injection timing. [13]

Jie Liu et all. (2015) Shows "Experimental and numerical study of the pollution formation in a diesel/CNG dual fuel engine"

In this paper, dual fuel combustion model comprising a modified turbulent flame speed closure (TFSC) model and a partially premix reactor model is developed and incorporated into the KIVA-3V code to simulate the combustion processes within the dual fuel engine. Numerical results are validated by the cylinder pressures, heat release rates and emissions of the corresponding experimental data. The results reveal that most of the pilot fuel vapour remains within the bowl, and the combustion of the pilot fuel forms a high temperature region. At low engine speed, the piston crevices are largely responsible for the creation of the unburned CH4 emissions. However, at high engine speed, bulk gas partial oxidation in the cylinder centre region is the major source of the CH4 emissions. The flame quench zone in the squish volume close to the cylinder walls is the main source of the CO emission at low engine speed. However, the bulk gas partial oxidation zone in the cylinder centre region is the major source of the CO emission at high engine speed. [18]

Musthafah Mohd. Tahir et all. (2015) Shows "Performance analysis of a spark ignition engine using compressed natural gas (CNG) as fuel"

In this paper a single cylinder spark ignition (SI) engine was selected in order to study the effect CNG into the spark ignition engine. The hydraulic dynamometer was used to study the performance of CNG and liquid fuel. The result showed that pressure inside cylinder for CNG is 20% less than gasoline. CNG fuel also produced 23% less heat transfer rate compared to gasoline. The results explained why CNG produced 18.5% lower power compared to liquid fuel (gasoline).So some improvement needs to be done in order to use CNG as fuel.

3. OBJECTIVE

- ➢ Experimental Investigations on fuel injection using CNG in Single Cylinder four Stroke SI Engine.
- ➢ Desired pressure (4 to 8 bar) will be injected in the intake manifold using CNG injector to Check the Performance.
- ➢ Speed and Load condition to check at different level for Engine performance.
- ➢ Engine economy, performance and efficiency will be improved.

4. EXPECTED OUTCOME

From the above literature survey it was observed that injection of fuel was mainly done through Mixer/Carburetor Injection, Single Point Injection, Multi Point Injection and Direct Injection. So here, I will deal with single point injection system where CNG and gasoline fuel are compared. So following things are expected through this project.

- ➢ Improving turbulence for better A/F mixtures for complete combustion.
- ➢ It may be increasing a thermal efficiency of engine.
- ➢ It may be decreasing the Fuel Consumption.
- ➢ Decreasing air pollution.

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