To increase the efficiency of CNG Car

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Abstract- **This study presents experimental test results of a compressed natural gas (CNG) direct injection (DI) engine, which has been developed by modifying a single cylinder diesel engine. The major modifications are (a) modification of components such as cylinder head, piston etc. and (b) development and deployment of electronic fuel injection system and (c) installation of a capacitive discharge ignition system. Tests were conducted at constant fuel injection pressure and engine speed to investigate the performance, emission and combustion characteristics of a CNG DI engine under different fuel injection timings (Start of injection; SOI) and varying engine load (Brake mean effective pressure; BMEP). Based on the experimental results, it was found that moderate engine loads (BMEP) lead to faster and more complete combustion and improved engine performance with relatively lower emissions for specific injection timings. Advanced fuel injections improve engine performance (lower BSFC, higher BTE); reduce engine emissions and produce faster and superior combustion whereas retarded injections show completely opposite trends for every engine load.**

Index terms- **Compressed natural gas; Direct Injection; Manifold injection; Engine performance**

INTRODUCTION

With emerging stringent pollution legislations and limited availability of liquid fossil fuels, demand for improving fuel efficiency and reduction of harmful emissions has become the prime thrust for the present engine researchers. Petrol engine have the advantage of higher power-to weight ratio compared to its diesel counterparts, but they suffer from the issue of relatively lower thermal efficiency due to unavoidable throttling and engine knock. Diesel engine has higher thermal efficiency; however, the emission of NOx and particulate matters still remain a major concern. In recent years, direct injection gasoline engine has emerged to fulfill the need of improve fuel economy but still suffers from the problem of harmful PM emissions [1, 2].

With the plentiful availability of natural gas and low emissions due to its favorable (H: C) ratio, Natural gas has emerged as one of the most promising and clean alternative fuels for engine applications. Furthermore, its high octane rating allows high compression ratios leading to higher thermal efficiency however CNG suffer from the problems of very low energy density. There are many CNG engine technologies used worldwide, which differ in the way the fuel is introduced into the cylinder e.g. carburetor technology, port injection, duel fuel technology, etc. To utilize the full potential of CNG in engine applications, concept of direct injection (DI) has been investigated under various engine operating conditions by varying fuel injection timings, equivalence ratio, cyclic variations, spark timings etc.

Richards et al. [3] reported that CNG DI engine have higher power output and higher thermal efficiency compared to a conventional spark ignited natural gas engine due to higher compression ratio, and lower pumping losses at the part load conditions. Ikeda et al. [4] found in their study that an eight cylinder CNG DI engine had twice the brake mean effective pressure as compared to conventional spark ignited CNG engine (port fuel injected). Caley et al. [5] performed a comparative study on manifold CNG injection, manifold gasoline injection and CNG DI system and discovered that manifold CNG operation leads to a performance reduction of 9-13% compared to manifold gasoline operation whereas performance with DI CNG is within 3% of stoichiometric gasoline performance at low engine speeds and within 7% at higher engine speeds. Direct injection of CNG with late injection improves air flow upto 10% over manifold CNG operation, which in turn increases engine performance upto 10% at lower engine speeds but at higher speeds, only 4% improvement in engine performance due to reduction in mixing duration. Yuichi Goto [6] investigated the influence of injection timings and spark timings on the combustion and exhaust emission characteristics of a single cylinder diesel engine and demonstrated that when λ is close to 1.0 (Stoichiometric mixture), combustion becomes stable by more advanced injection and when λ is more than 2.0, retarded injection provides more stable combustion. Zeng et al. [7] showed that with advanced fuel injection timings, HC emissions decrease but NOx emission increase due to adequate fuel-air mixing and complete and faster homogeneous combustion, whereas retarded injection lead to opposite trends. Liu et al. [8] investigated the influence of fuel injection timings and spark timings on combustion and emission characteristics of a spark ignited CNG DI engine and reported that advanced fuel injections lead to better air-fuel mixtures, promoting formation of flame kernel and thus reducing initial combustion duration, however, the rapid combustion duration is prolonged slightly. Huang et al. [9, 10] investigated the basic behavior of CNG DI combustion in a spark ignited rapid compression machine (RCM) with different injection modes and showed the same.

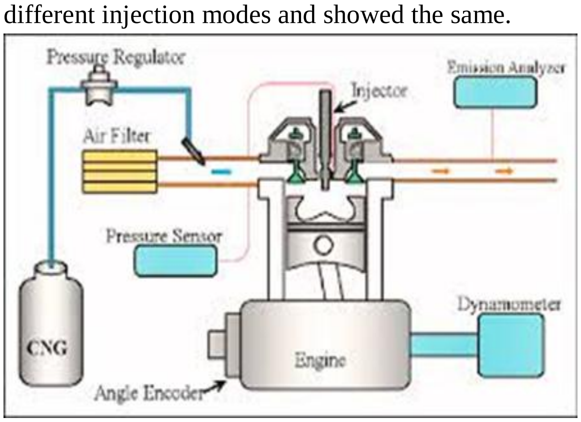
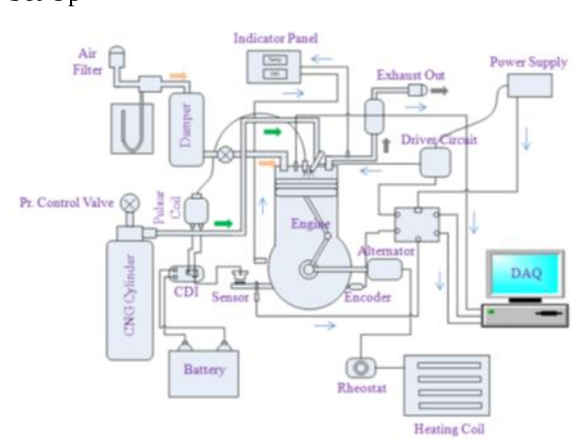


Figure 1 .Working of CNG Engine

CO increased steeply with the increase in equivalence ratio, when equivalence ratio was greater than 0.8 and NOx emission peak shifts to the region of lower equivalence ratio. Results also showed that heat release pattern of early injection showed a slower combustion in the initial stages and a faster combustion in the later stages, which is similar to that of premixed gas. Whereas for late CNG injection, the heat release pattern showed faster combustion in the initial stage and slower combustion in the later stage, which is similar to diesel combustion. Early injection leads to a longer duration of initial combustion, whereas late injection leads to a longer duration of the late combustion. Most of the CNG DI researches are performed in RCM and provide some useful insight, however, the real in-cylinder gas flow and combustion between them makes it difficult to understand the effect of fuel injection timing on CNG DI combustion. Therefore, a systematic experimental study on the effect of fuel injection timing into an IC engine is worth investigating. The objective of the present study is to experimentally investigate the combustion behaviour at varying loads and injection timings in a direct injection natural gas engine in order to develop better understanding of CNG DI engine.

Set Up



Fgure 2.Set up for CNG Engine

The major modifications done on the test engine are (a) cylinder head machining to accommodate both spark plug and CNG injector in their respective optimized positions, (b) modifications in piston bowl in order to reduce the compression ratio, (c) installation of capacitive discharge ignition system for the spark plug and (d) development and deployment of electronic fuel injection system. A gasoline direct injection injector (GDI) injector (Model:

DIM1000G E7T05071, Mitsubishi, Japan) was procured and used to supply CNG directly into the engine combustion chamber at 50 bar pressure and the opening, closing of the injector and injection duration was controlled by a custom made electronic circuit, which uses TDC signals from a proximity sensor (GLP18APS, TAP). The calibration of the fuel quantity injected with the injector pulse width was carried out in the laboratory. An ignition system having pickup coil, capacitive discharge ignition (CDI) coil and a long tip spark plug was installed onto the engine.

An alternator was coupled with the engine to apply load on the engine. The air flow rate into the engine intake manifold was measured using an orifice plate and U-tube manometer installedcross an air box. CNG mass flow meter was used to measure the CNG mass flow rate into the engine. A piezo-electric pressure transducer (6613CQ09-01,Kistler Instruments, Switzerland) was mounted flush with cylinder head and the in-cylinder pressure data vis-a-vis crank position signals from a shaft encoder (ENC58/6-720AB, Encoders India) was acquired by a high-speed combustion data acquisition system (Synergy, Hi-Techniques, USA). For the analysis for combustion characteristics, average data set of data acquired for 100 consecutive cycles was used.

Raw exhaust emissions were measured using exhaust gas emission analyzer (444 Digas, AVL,
Austria) and smoke opacimeter (437, AVL, Austria). The engine was operated in steady-state condition with wide open throttle (WOT) at constant engine speed of 1500 rpm and spark

Results and discussion

The Evaluation Evaluation based on Performance: CNG burns at a high octane rating of 130 and performs better• than Petrol powered vehicles under cold start conditions. CNG Vehicles have better horse power and cruise speed just like petrol. In terms of Kilometers (Km) per litre, a light duty Compressed Natural Gas Vehicles will get about the same Km per equivalent litre of Natural Gas as it does on Petrol. CNG provides easy starting, reliable idling and smooth acceleration. When CNG vehicles are running, its acceleration is a bit slower due to loss of Power typically 5-15% which can be minimized by proper tuning on the CNG Kit (e.g advancing the spark timing) to take advantage of the high octane rating of the fuel. The power loss on CNG is not noticeable in ordinary city driving. Evaluation based on Storage and Safety: Firstly, CNG has four big safety features that make it an• inherently safer fuel than petrol: CNG has a specific gravity of 0.587 which means that it is lighter than air so if it leaks, it just rises up and dissipates into the atmosphere. Secondly, CNG has a self-ignition temperature of 700 degree centigrade as opposed to 455 degree centigrade of petrol. Thirdly, CNG has to mix air within small range of 4 to 14% by volume for combustion to occur. This is far narrower range than petrol. Fourthly, CNG cylinders are designed and built with special materials to the highest safety specification which make storage far safer than petrol tanks. The CO on CNG is very lower compared to petrol and it's a relatively clean burning fuel as compared to petrol. Evaluation based on Maintenance: The recommended maintenance scheduled for CNG vehicles are• similar to those for petrol fueled vehicles because CNG burns clearly than petrol, CNG powered vehicles requires less maintenance, including fewer oil changes and less frequent spark plug replacement. High pressure tanks require periodic inspection. CNG vehicles are equipped with high pressure storage tanks capable of storing CNG to about 200bar. Evaluation based on Emissions: CNG burns more completely than petrol and emits lower amounts of• all the regulated exhaust pollutants. Carbon dioxide emissions are also lower in CNG than emissions from petrol powered vehicles, but methane levels are higher. Methane's ability to trap heat in the atmosphere or its global warming potential is 21 times greater than that of carbon dioxide. Evaluation based on Economy and Cost: Currently, all alternative fuelled vehicles have a price• premium over traditional fuelled vehicles (unless manufacturers have special promotional prices that they subsidized). With more vehicles coming into the market, certain economies of scale will be achieved. The price of a CNG vehicle varies depending upon whether it is a petrol vehicle converted to run on CNG or a factory built vehicle. Different size vehicles also vary in price, typical seldom are less expensive and trucks, which requires more storage cylinders are more expensive. CNG vehicle conversion equipment can be purchased for about €4000 (4000 Euro) and installed by fleet owners who can receive training from the conversion companies or conversion kit manufacturers. Alternatively, CNG vehicle specialist can do the conversion which adds about 25% to the vehicle cost. Larger vehicles requires more fuel storage cylinders and the price can increase depending on how many cylinders and the type installed. Light duty CNG vehicles from the factory can range in price from €1000 - €6000 over the price of a traditional fuelled vehicle. Heavy duty engines, trucks and buses typically cost €30,000-€50000 more than standard petrol engines and vehicles. Evaluation based on Technology: There are some recent important advances in CNG vehicle• technology that will keep the industry on track with the most advanced technologies being produced by the major automotive manufacturers. CNG vehicles now are compatible with computerized fuel injected engines. They are superior to petrol vehicles because CNG is injected directly into the combustion chamber in its gaseous state without having to go through a special gas/air mixer. The newest system are "closed loop", they are part of the systems that include oxygen sensors in the vehicle tail pipe, and provides feedback to the engine control systems to alter the fuel/air ratio depending upon the requirements of a vehicle's performance at any given time. Evaluation based on refueling of the Vehicles: Natural gas is compressed and vehicles can be• refueled directly from the compressor on a slow fill basis (about five to eight hours) or can be refueled in one to two minutes using compressed gas stored in cascades of CNG cylinders (multiple gas cylinder interconnected). Many privately owned refueling stations use a combination of fast fill and slow fill, depending upon the individual needs. Evaluation based on fueling station cost: Installation of a compressor station to refuel the CNG• vehicles is an additional expenses, if public refueling is unavailable. Some utilities are providing compressor station equipment free, or are making special arrangements with fleet operators to provide the Natural Gas in the form it is used-compressed. Depending upon the design of the station, the number of vehicles to be refuelled.

Fuel storage requirements, compressors and related equipment can cost from €5000-€10000 (for small compressors) to €40000 or more for stations capable of serving hundreds of vehicles. Bus fueling stations, where 3 minutes quick fill is required for large numbers of vehicles can cost €1 million or more. For normal fleet vehicles, however as a general rule, you can expect to spend €1000-€2000 per vehicle to install a fueling station. Evaluation based on engine conditions: CNG has no harmful effect on the engine. On the contrary,• the life of an engine increases by using CNG. Lubricating oil life is extended considerably because CNG does not contaminate and dilute the crankcase oil. Due to the absence of any lead content, lead fouling of plugs is completely eliminated and the plug life is greatly extended. Another aspect which increases engine life is that, CNG enters the engine in the form of a gas whereas petrol enters in the form of spray or mist. This spray/mist washes down the lubricating oil from the piston rings and thereby increases the rate of depreciation of the engine. Since this is not the case when using CNG, the life of the engine is increased, on the whole, the maintenance costs are reduced and engine life is increased. Evaluation based on legislations and incentives: incentives encouraging the use of CNG vehicles• differ by country. For example: there are special tax provisions that reduce fuel taxation in Germany, Sweden, and the UK, in Belgium, Ireland , and Italy there is no fuel tax on Natural Gas as a vehicle fuel, making it economical compared to other competitive fuels. In Germany, the Ministry of the Environment ran a competition worth DM5 million, which it awarded to the city of Augsburg as a promotion for CNGVs. Other incentive programs are developing slowly in Europe. Evaluation based on the market place: The most important element missing in the market place is• deep enthusiasm on the part of the majority of the Natural Gas industry, which would rather market to the "big pipe" customers like co. generators than work to diversify into a vehicle transportation market of smaller customers looking for Environmental friendly ways to stay economically competitive. The CNG vehicle business today could very well pave the way into the twenty first century when fuel cells might be a major market contributor to cleaner vehicles of tomorrow fuelled by hydrogen reformed from Natural Gas. Unfortunately, many Gas Company Executives look out onto a parking lot filled with petrol and diesel vehicles instead of CNGVs. When it comes to the CNGV market of the twenty first century, too many of these same Executives are peering into the future through the wrong end of the binoculars. Evaluation based on adequacy of fuel supply: Natural gas (CNG) is very adequate for S.I engines• due to its octane number as drawn from sermin (2009) research work. Evaluation based on process efficiency: The results from Mr. Saravanan V.D. Dr. P.S Utgika (2013)• and mardani

Ali sera (2008) research showed that, CNG has low volumetric efficiency due to low density and under the same engine operations and configurations, CNG shows 20% reduction in Mechanical efficiency. But Kalam et al (2005) says there will be increase in efficiency when a turbocharger is used with a corresponding increase in emissions.

Conclusion

The main focus of this review work was to evaluate the comparative analysis of previous work done in the use of CNG and Petrol as vehicular fuel and as a result, the following conclusions were drawn as follows: CNG has low Volumetric Efficiency and 20% reduction in Mechanical Efficiency.

- CNG has no harmful effect on the engine and it si very adequate for S.I engines
- CNG burns more completely than petrol and emits lower amounts of all the regulated exhaust pollutants
- CNG powered vehicles requires less maintenance, including fewer oil changes and less frequent spark plug
- Replacement. It can be concluded that CNG vehicles have better horse power and cruise speed just like petrol
- CNG has higher engine thermal efficiency and exhaust gas temperature
- CNG produces less than 8-16% of brake torque, brake power and BMEP compared to petrol due to reduced
- volumetric efficiency and lower flame speed of CNG CNG has 19% brake specific fuel consumption (BSFC) compared to petrol

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