Analysis of Different Injection Strategies in Compressed Natural Gas Operated Engine – Review

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Abstract — The objective of review is to get more information about the CNG(compressed natural gas) and detail study on different methods of injection for getting the conclusion that how much research work is been done on this till date. After detail study conclusion came out that research is done on individual methods but no one has compared two methods of injection tighter at one time so per conclusion the research gap should be done on the finding the comparatively best output between port and sequential injection method on CNG fuel to find out which injection method is best for injecting CNG to make sure the best method several properties are to be taken to find the perfect reading. The main thing in this reading is it will be taken on different rpm different load so reading can evaluate perfect.

Keywords: CNG as Alternative Fuel, Port Injection, Sequential Injection, Direct Injection, CNG, Engine

I. INTRODUCTION

The natural resources like petrol diesels etc are near to extension on behalf of that we all need some other source or fuel to run the vehicle many scientist are working on it word wide to find new fuels which work in the engine and produce the power and also be less emitted and harm the nature one of the natural gas called CNG(compressed natural gas) is been used for long time in absents of petrol and CNG as alternative fuel and it is giving good output.Natural gas is one of the most promising alternative fuel for conventional vehicle engines because, it has cleaner combustion characteristics and huge reserves, It has high-octane number value (130) and good anti-knock property which permits high compression ratio about (11-13) results into higher thermal efficiency under high load condition, engines fuelled with natural gas emit less carbon-monoxide and non-methane hydrocarbons compared to gasoline engines, CNG has higher self ignition temp about (650-700°C) makes it a safer fuel in case of leakage and that means fire hazards occurs very less in CNG vehicles Therefore, the natural gas engines are widely used in stationary and transient applications all over the world.

Component	Symbol	Volumetric %
Methane	CH_4	94.42
Ethane	C_2H_6	2.29
Propane	C_3H_8	0.03
Butane	C_4H_{10}	0.25
Carbon dioxide	CO_2	0.57
Nitrogen	N_2	0.44
Others	(H_2, O_2, S, etc.)	2

Table 1: Typical composition (vol. %) of CNG [1].

II. LITERATURE REVIEW

A. CNG as an alternative fuel

When CNG is used in internal combustion engines it gives good compromise in efficiency, cost, and emission Due to its higher octane number, engine efficiency can be increased through higher compression ratios. It also has lower emission in output emission concerns Emission concerns related to engines and the adverse effects brought on health and environment along with the search for other sources of energy continue to be two important issues of discussion in automotive industry and day by day the effect of pollution will be increased in world. So for these reason the research is been performed on alternative fuels such as methanol, ethanol, butanol, Natural Gas (NG), and Liquefied Petroleum Gas and CNG is most effective one among all of these alternative fuel Natural gas consists mainly of methane with small amount of ethane, propane, and butane. Very small concentrations of inert gases such as N2 and CO2 are also present. Methane exists in natural gases in percentages of up to 90 to 95%.This paper briefly review aspects of CNG use in I.C. Engines from resources, metering, storage, combustion, emission, and efficiency points of view. In conclusion of this paper we get that Natural gas seems to have good properties among alternative vehicular fuels. Combustion chamber design is most imp factor in use of natural gas in IC engines lean burn will provide maximum efficiency in use of natural gas and the natural is powerful then gasoline one because it requires more power full ignition then gasoline [2]There are many alternative fuels which are available in market and CNG is one of them it is been used in stationary engines since ling time but by little modification and changes lightweight high-pressure storage cylinders were made and CNG was used of transportation engines also for spark ignition engine there are two ways bi-fuel conversion and use a dedicated to CNG engine. For compression ignition engines converted to run on natural gas, also has two main options dual-fuel engines and normal ignition can be initiated, in this paper CNG power torque output is compared to gasoline and diesel engines output [3].

B. Different injection methods for CNG

There are four methods to inject the CNG into the engine cylinder.

1) Gas mixer / carburettor injection The air/gas mixture is formed in the air-induction manifold and then it passes through carburettor and enters in the cylinder during suction stroke due to vacuum created
2) Single point injection (Port Injection) or (conventional CNG Injection)It is similar to gas mixer/ carburettor injection the carburettor is replaced by petrol injectors in euro 2 norms the CNG injection pressure is kept up to

1.5-2.5 bar, and CNG is injected by mixer in the air intake manifold.

3) Multi point injection (Sequential Injection) this is sophisticated approach of CNG injection. The CNG is injected in port (just near the valve) through special gas injector rail, the individual gas injector will inject right quantity of CNG at right time and injection process is controlled by CNG ECM, it generates higher volumetric efficiency and higher the volumetric efficiency hence higher thermal efficiency.
4) Direct CNG Injection (CNG-DI) The CNG-DI engine system is more suitable where the fuel is injected through a high pressure pipe line straight into the cylinder with the required amount to produce similar or higher brake power than gasoline engine [4]. In port injection CNG engines, gaseous fuel is injected by fuel injector through intake port into combustion chamber. This paper works shows improvement for air-fuel mixing in the combustion chamber by the use of pressurized flow of CNG inside the cylinder with the help of CNG injector through intake port. The medications are done on the intake fueling system. For fuelling system the port injection method of CNG gas is to be used because of major drawbacks limitation for other types of injection systems on the basis of availability, installation and emission point of view. Experimentation work carried out on a Greaves made engine having cubic capacity of 600cc dedicated CNG engine and the effects of CNG injection through modification of combustion chamber geometry on the engine performance in terms of parameters like Brake torque, Brake power, BMEP, BSFC, and Exhaust gas temperature of the engine was examined[4].
5) In this experiment the gasoline injection engine was converted into BI fuel engine which runs on CNG and gasoline with sequential injection method controlled computer integrated installment then the engine was run from 1500 to 5000 rpm at 500 speed increment and that time all reading was recorded then it was found that this engine produced higher fuel conversion efficiency and lesser brake specific fuel consumption then carburetor engine however volumetric efficiency was reduced a little bit due to that torque brake horse power and brake mean effective pressure was reduced but in terms emission of HC CO CO_2 compared to gasoline[5].
6) Study in this paper presents experimental test results of a compressed natural gas in direct injection engine, which has been developed by modifying a single cylinder diesel engine. For that modifications are one on the engine like, modification of components such as cylinder head, piston etc, development and deployment of electronic fuel injection system and, installation of a capacitive discharge ignition system. Tests will be conducted at constant fuel injection pressure and constant speed to get the performance, emission and combustion characteristics of a CNG DI engine under different fuel injection timings and varying engine load Based on that result it was found that moderate engine load leads faster combustion and efficient one And advanced fuel injection improves engine performance reduce emission and produce faster combustion while retarded injections show completely opposite reading for every engine load [6].
7) The engine will aid in advancing technology and understanding the operation of compression-ignition (CI) engines using natural gas within the heavy-duty engine industry. The basis for the engine is a Cummins 15L ISX engine that has been modified, retrofitted, and instrumented to allow for late- cycle direct-injection of high-pressure compressed natural gas. Along with the engine build, a one-dimensional GT-Power simulation model has been created and used to analyze the engine operation and specify components including the engine compression ratio and charging system. The combustion model was calibrated to a kinetic combustion model at multiple speed load points in effort to understand the effect of compression ratio, temperature, and start of injection, on natural gas compression ignition [7].
8) This paper presents experimental test results of a new compressed natural gas direct injection engine which is been developed by some modification of a multi cylinder petrol port injection engine. The major modifications which are held is, injection system has beenmodified to gas direct injection using new high pressure gas injectors, compression ratio has been changed from 10 to 14, new spark plugs with long edge were usedto ignite the CNG fuel and The CNG pressure at commonrail was kept at 20 bar to be injected into engine cylinder.The engine has been operated with full throttle conditions to compare all the results with original gasoline port injection engine and the CNG bi-fuel engine where the base engine has been converted to bi- fuel injection system to be operated with gasoline and CNG fuels. Hence, it can be mentioned that the original gasoline port injection engine has been modified to CNGbi-fuel and CNG-DI systems. The test results obtained from CNG fuel using two different systems willbe compared with original gasoline engine in the test emission and specific fuel consumption are main factors which is to be under taken to get the reading the objective of this investigation is to compare the test results between "CNG-DI", with "CNG-BI" and "gasoline - PI" engines withthe same displacement volume. It was found that the CNG-DI engine produces higher brake power at same rpm compared to original gasoline engine. The CNG-DI engine produce more power than. The CNG-DI engine reduces 50% NO_X emission as compared to base engine. However, the CNG-DI engine produceshigher HC and CO emissions as compared to base engine by 34% and 48% respectively [8].

C. Using different criteria of injection on CNG engine

Natural gas is very effective alternative fuel compare to gasoline it can replace the conventional fuels the use of Compressed Natural-Gas (CNG) in spark-ignited (SI) engines can reduce CO2 emissions by up to 20% compared with gasoline operation. Currently, all spark-ignited CNG engines are port injection method engines but they suffer loss of power due to a reduction in volumetric efficiency but Direct-Injection can overcome this drawback and can improve the torque and power output. In this experimental study, we do experiments on CNG engine by changing

injection timings and that comes out with different effects the effects of injection timing, before and after the inlet valve closure on combustion duration and engine thermal efficiency at low load and WOT (Wide Open Throttle) conditions. At low-loads, late-injection increases pumping losses compared to early-injection at a given loading condition but combustion is faster due to higher turbulence at the time of ignition. As a result, the thermal efficiencies are similar at these injection timings [9]. The objectives this paper is to design and investigate the injector nozzle multi holes and the effect on air- fuel mixing in combustion chamber of sequential port injection CNG engine based on variation intake valve lift using Cosmos Flow simulation. The simulation of injected gas fuel and intake air mixing in the combustion chamber of new injector nozzle multi holes geometries effect is conducted in 1.78mm, 3.55mm, 5.33mm and 7.10 mm intake valve lift and in 1000 rpm engine speed. The results are shown, that the 4 holes injector nozzle is has the best in air-fuel mixing [10].

III. Conclusions

After surveying literature reviews it is been clear about the CNG fuel, it is been used for mainly reducing usage of conventional fuel and it also one of the best alternative fuel and also learned about different methods of CNG injection, but mainly looking after all research papers one thing was missing that was comparison of any of the methods together showing which method is best, after review of papers it is been clear that direct injection is been found but not applicable on real life use so mainly port and sequential are used so this both method need to be compare at same parameters and see which one is best at which stage.

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