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Effect of Compression Ratio on Performance and Emission of CNG fulled S.I. Engine Modified from the C.I. Engine: Experimental Investigation

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Abstract— This paper presents the performance results of a 5.5kW Crompton Greaves make GL-400 diesel engine which was converted into spark ignition mode and run on compressed natural gas (CNG) at different compression ratios in range of 10 to 13.1 at load varying from 18% to 72% at 1800 rpm. Performance of engine found better at 12.4 CR for modified diesel engine fuelled by CNG. Modified engine efficiency found lower compare to diesel engine in range of 6 to 22% at 1800 rpm. Emission of CO, CO_2 and HC were reduced for modified engine compare to diesel engine.

Keywords- Compression Ratio, Compressed Natural Gas (CNG), C.I Engine, S.I. Engine.

I. INTRODUCTION.

Air pollution is fast becoming a serious urban as well as global with the increase pollution and its subsequent demands. This has resulted in an increase interest in using natural gas (NG) as fuel for internal combustion (IC) engines. NG resources are vast and widespread geographically and are not limited to politically sensitive location as is typical for crude oil. Base on current consumption rates the estimated total, recoverable gas, including proven reserve, is adequate for almost 200 years [2]. Any researcher was researched about the compresses natural gas as alternative fuel motivated by the economic, emissions and strategic advantages of alternative fuels. Several alternative fuels have been recognized as having a significant potential for producing lower overall pollutant emissions compared to gasoline and diesel fuel. Shasby identified three reasons to used natural gas as a transportation application, first reason is availability, the second attraction reason of natural gas is its environmental compatibility and the third attraction reason of natural gas is that it can be used in conventional diesel and gasoline engines [3]. Operating cost is another reasons, where natural gas powered vehicles theoretically have a significant advantage over petroleum-powered vehicles, the basis for this argument is the lower cost per energy unit of natural gas as compared to petroleum [3].

India is a diesel-based economy. Diesel consumption is around five times the consumption of petrol [5]. To benefit from the use of CNG in engines, it is necessary to understand its combustion under the appropriate condition and to study the effects of various parameters on it.

This experimental investigation aims to understand the effect of higher compression ratio on performance parameters of CNG fuelled engine S. I. engine modified from the C. I. engine.

II. CNG AS AN ALTERNATIVE FUEL FOR IC ENGINE.

Natural gas significantly reduces CO2 emissions by 20-25% compare to gasoline and diesel because simple chemical structures of natural gas (primarily methane-CH4) contains one carbon compare to diesel (C15H22) and gasoline (C8H18) [1]. CNG defuses in air fuel mixing at lower inlet temperature than is possible with either gasoline or diesel. This leads to easier starting, more reliable idling, smoother acceleration and more complete and efficient burning with less unburned hydrocarbons present in the exhaust [2]. CO exhaust emission is also reduces during by using CNG as a fuel. It has also a wider flammability range than gasoline and diesel oil [1].The higher ignition temperature of gas compared with petroleum based fuel leads to reduced auto ignition delays. Due to the higher ignition temperature, CNG is less hazardous than any other petroleum based fuel. The higher octane rating (120) for CNG as compared to that of gasoline (87) allows a higher compression ratio (CR) and consequently more efficient fuel consumption. Due to higher CR, CI engines can also use CNG as a fuel, but since cetane rating for CNG is poor, it cannot replace diesel totally like gasoline without modification [2]. CNG defuses in air fuel mixing at lower inlet temperature than is possible with either gasoline or diesel. This leads to easier starting, more reliable idling, smoother acceleration and more complete and efficient burning with less unburned hydrocarbons present in the exhaust [2]. It has also a wider flammability range than gasoline and diesel oil [1].

Table 1. Important properties of CNG and diesel [1, 2, 15]

Properties	**Diesel**	**CNG**
Chemical formula	$C_{12}H_{26}$	CH_4
State	Liquid	Gas
Lower heating (kJ/kg) ((value(kj/kg)	42600	45000
Octane rating	-	120-130
Cetane rating	40-55	--
Auto ignition temp.(K)	493	723
Stoichiometric ratio	15	17.6
Flash Point ° C	74	-104
Freezing Point ° C	-40 to-1	-182
Boiling Point ° C	188-343	-162
Latent heat of vaporization kJ/kg	233	510
Density at 15^0 C, (kg/m^3)	832	--
Flame Speed (m/s)	0.4	0.34
Flammability Limits (volume % in air)	1.0-6.0	5-15

For compression ignition engines conversions to spark ignition, the pistons must be modifies to reduce the original CR or shims to be inserted between cylinder block and crank case body and a high-energy ignition system must be fitted. The system suitable for CNG is port injection system.

III. REASONS TO MODIFY DIESEL ENGINES CONVERSION IN TO SI PORT INJECTION CNG ENGINES.

- The problem of air pollution around the globe is real and serious, diesel exhaust emissions are a major source of pollution in most urban centers around the world and a major contributor to climate change. Trucks, buses, generators and ships burn millions of gallon of diesel fuel daily. Many countries are to alternative fuels to reduce diesel exhaust emissions, especially in urban centers.
- Furthermore, as the price of crude oil continues to increase, the use of alternative fuel becomes increasingly economical and reduces the import burden of oil country like India.
- Price of diesel is low compare to petrol and has higher efficiency than petrol so people of the urban area are switched over to the diesel engine which make a serious problem in urban are to solve this problem higher efficient and economical operated CNG fuelled diesel engine is required.
- CNG fuels are more suitable for higher compression engines since they resist knock more than conventional liquid fuels (due to high octane value that permits a high compression ratio, leading

to higher thermal efficiency at full-load condition) as well as produce less polluting exhaust gases, if appropriate conditions are satisfied for their mixing and combustion[14].

- CNG does not contain lead or benzene, thus eliminates lead fouling of spark plugs and lead or benzene pollution.

IV. MODIFICATION DONE TO CONVERT DIESEL ENGINE IN TO CNG FULLED S.I. ENGINE.

- Engine compression ratio lowered by inserting metal shims.
- Spark ignition system installed and spark timing set 25° before top dead centre.
- Fuel injector removed and cylinder head modified to installed spark plug
- Tappet adjustment has been done.
- Flywheel change due to lower compression ratio and to install magnetic and pick-up coil behind it.
- Port injection system for CNG and air.
- CNG kit.

V. EXPERIMENTAL SET-UP AND METHODOLOGY

A Experimental engine test rig.

Fig1. Actual experimental set-ups for modified engine (CNG engine)

5.5 kW, single cylinder, air-cooled diesel engine having 3600 rpm was converted into spark ignition mode for utilization to CNG fuel. Fig.1 show actual arrangement of experimental set-up of modified CI engine in to CNG fuelled SI engine.

The main components of the experimental engine test rig were:

- Modified engine: a single cylinder Crompton Greaves India Limited make(Model GL-400) with original fuel injection set at 25° before TDC was used for the study. The diesel engine was converted into a CNG engine with necessary changes in the basic engine such as removal of fuel injectior, reduction in CR in range of (10 to 13.1),
- Compression ratio of diesel engine was reduced by inserting shims.

- Electrical Dynamometer: Electrical dynamometer is coupled with engine by coupling and out put of it is lead to resistive load bank and measure ampere and voltage with A-meter and Voltage meter
- Resistive load bank: Consist of lamps and load was varied in range of 0 to 72% in step of 18%.
- Air box with U-tube manometer:Air box with U-tube manometer is used to measure air consumption during the combustion.
- Infrared gun to measure exhaust gas temperature
- Digital tachometerto measure rpm of the dynamometer coupled with engine
- Ampere meter to measure output of electrical dynamometer
- Volt meter to measure output of electrical dynamometer
- Burette for Diesel flow measurement.
- Weigh scale to measure CNG fuel consumption.
- Exhaust gas analyser: Four gas analyser to measure exhaust emission of CO,CO_2, HC and O_2.
- CNG kit with carburettor to supply fuel and air to the engine

B Experimental procedure.

Engine testing has been done with diesel and after that engine has been modified and reading has taken. During experimental work 1800 rpm taken as constant rpm for varying load from 0 to 72% in step of 18% and measured the performance of engine by measuring fuel consumption, air consumption, generated voltage & ampere, rpm, exhaust gas temperature and exhaust gas emission at every load conditions.

Calculation of performance parameter like brake power(BP), brake specific fuel consumption(BSFC), brake thermal efficiency(BTE) and volumetric efficiency(VE) and exhaust gas emission. Convert them at reference condition as per IS-1000 procedure so it can be used at worldwide.

VI. RESULTS AND DISCUSSION.

The parameter of engine performance on diesel and after modification on CNG for no load and varying load conditions at 1800 rpm. The average values of each engine performance parameters are presented below in detail.

A Brake power

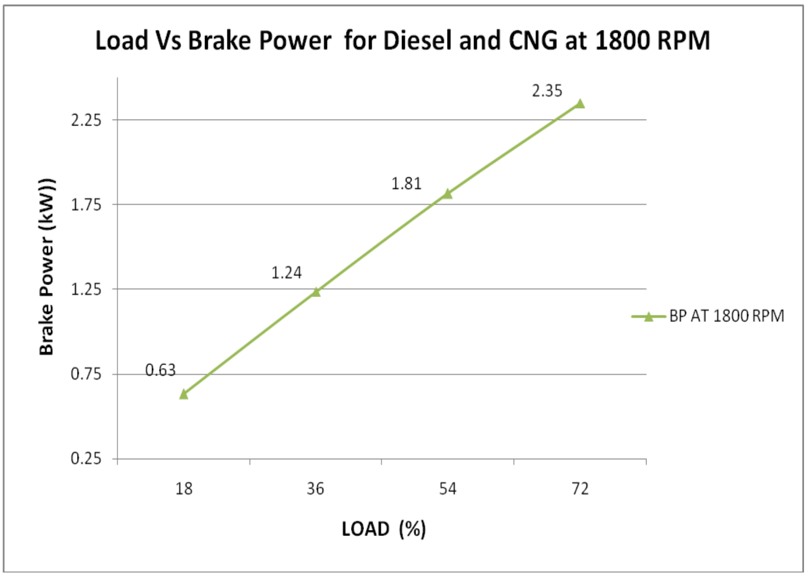

Fig2. Load Vs Brake Power at 1800 rpm for both diesel and CNG.

Fig.2 shows the correlation between the brake load (%) and brake power (kW) developed by the engine while operating on diesel and CNG. The brake power developed by the engine was found increasing with increase in brake load (lamp load) for the both the fuel.

Maximum brake power generated at 1800 rpm with this engine is 2.35 kW, here we consider electrical dynamometer efficiency 85%. Only fuel consumption is changed at different load condition with fixed rpm and different CR at 1800 rpm there is no change in generated power.

B Brake specific fuel consumption

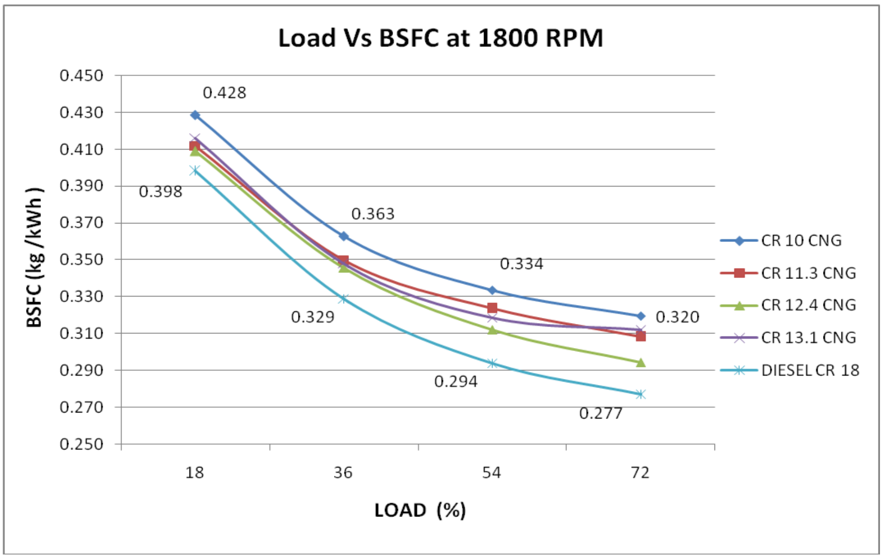

Fig3. Load Vs Brake Specific Fuel Consumption at 1800 rpm for both diesel and CNG at varying CR.

As shown from Fig.3 that at 1800 rpm for 18%, 36%, 54% and 72% load condition diesel brake specific fuel consumptions were 0.398 kg/kWh, 0.329 kg/kWh, 0294 kg/kWh and 0.277 kg/kWh respectively and for CNG engine at 12.4 CR were 0.409 kg/kWh, 0.346 kg/kWh, 0.312 kg/kWh and 0.295kg/kWh respectively, that is minimum compare other CR in CNG engine.

C Brake thermal efficiency

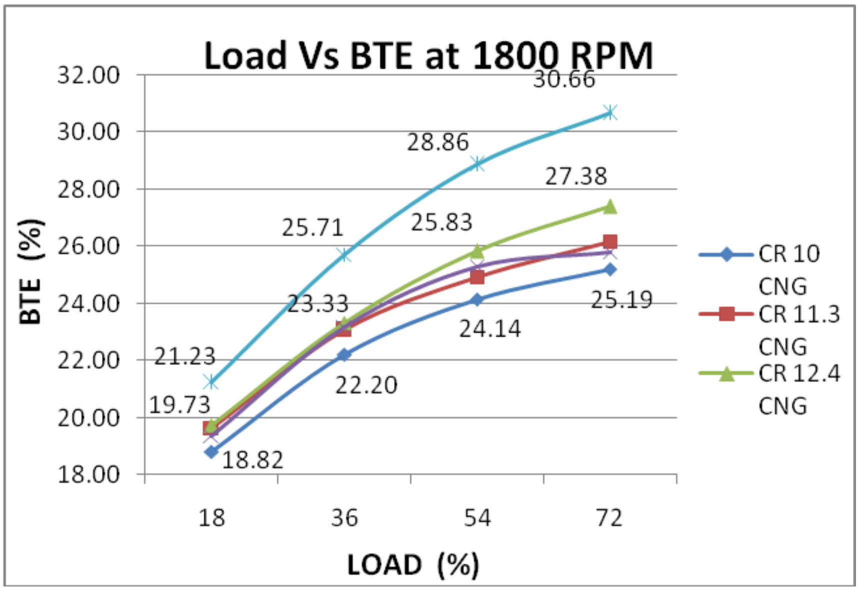

Fig4. Load Vs Brake Thermal Efficiency at 1800 rpm for both diesel and CNG at varying CR.

As shown from Fig.4 that at 1800 rpm for 18%, 36%, 54% and 72% load condition diesel engine brake thermal efficiency were 21.3%, 25.71%, 28.86% and 30.66% respectively and for CNG engine at 12.4 CR were 19.73 %, 23.33%, 25.83% and 27.38% respectively. It cleared from graph that at 12.4 CR CNG has maximum efficiency; it is also 6 to 22% less compare to diesel engine.

D Volumetric efficiency

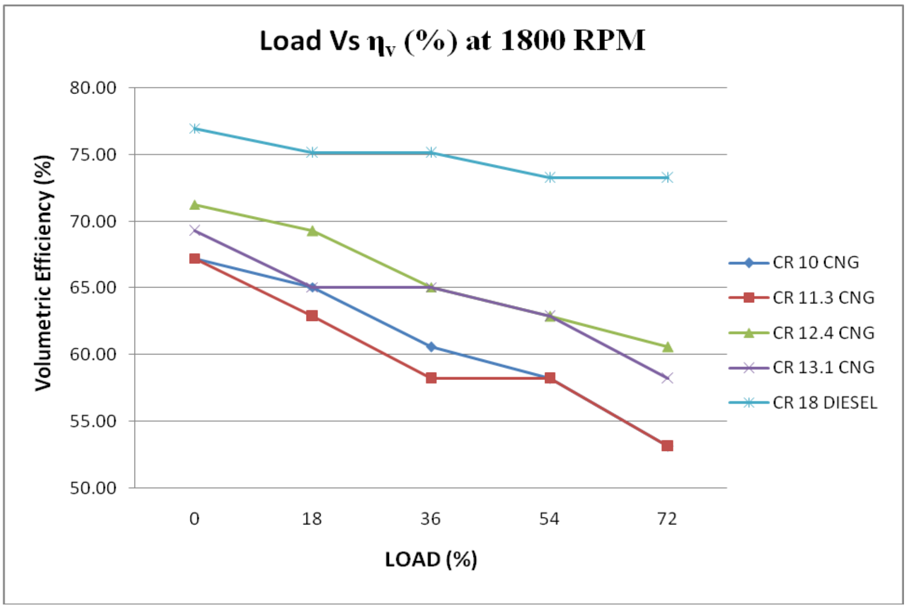

Fig5. Load Vs Volumetric Efficiency at 1800 rpm for both diesel and CNG at varying CR.

It is clear from Fig.5 that CNG engine has lower volumetric efficiency than diesel engine, but it has no clear trend with different CR in CNG engine.

E CO2 emissions

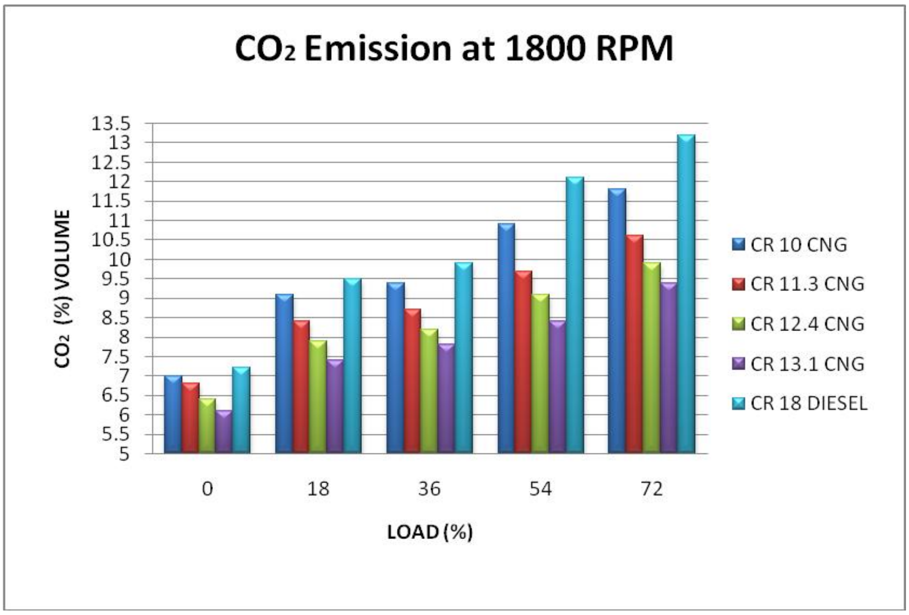

Fig6. CO2 emission at 1800 rpm for both diesel and CNG at varying CR.

CO_2 emission were increased as the load increased and it is decreases for the same load at higher compression ratio

F CO emissions

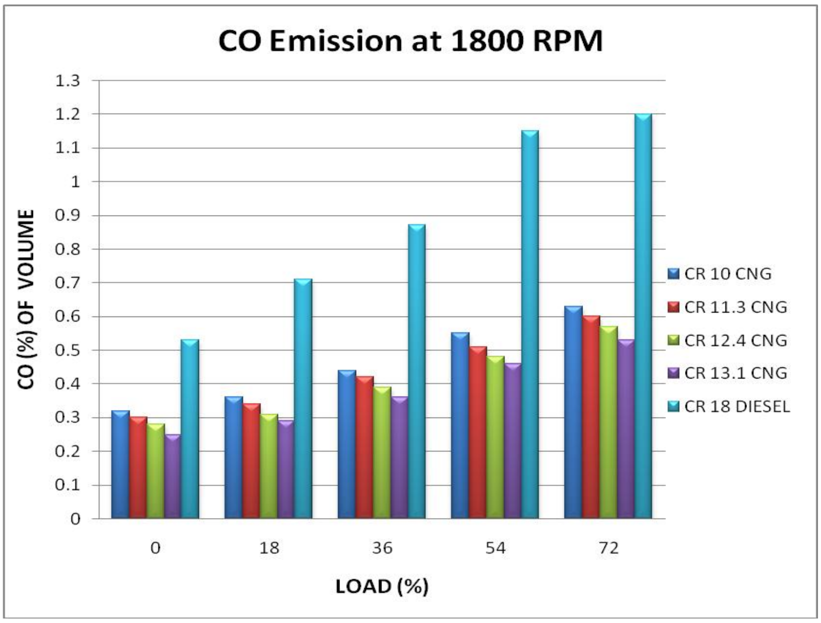

Fig7. CO emission at 1800 rpm for both diesel and CNG at varying CR.

It is cleared from Fig-7 that CO emissions are very low compare to diesel engine at all CR. As the CR increased CO emissions were decreased.

G HC emissions

HC emissions were found also low in CNG engine compare to diesel engine. As CR increased there were decrement found in the HC as showed in Fig.8.

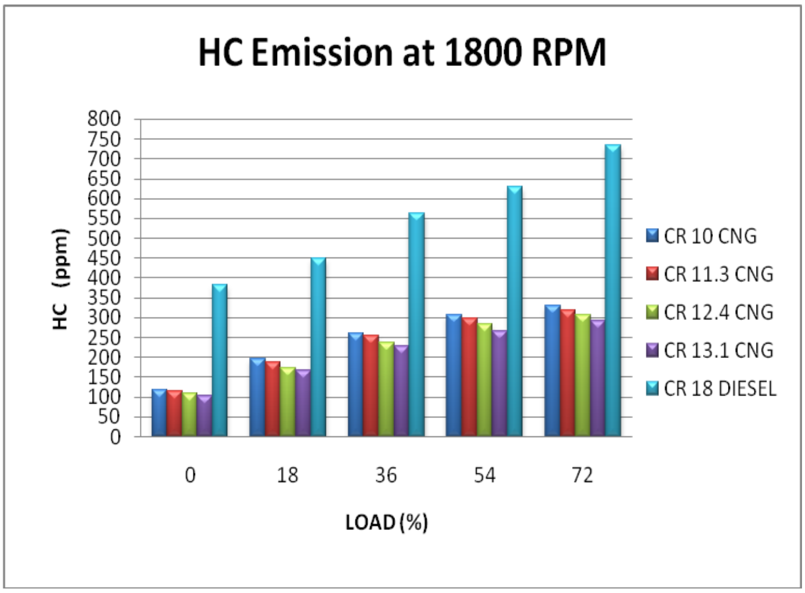

Fig8. HC emission at 1800 rpm for both diesel and CNG at varying CR.

VII. CONCLUSIONS.

It is concluded that specific fuel consumption in CNG engine is higher compare to diesel engine and its thermal efficiency were found low. In modified CNG engine BSFC and BTE found more at 12.4 CR in compare to other mentioned CR. Exhaust emissions of CO,CO_2 and HC were found lesser compare to diesel engine. At 13.1 CR emissions of gases were found lesser compare to 12.4 CR but fuel consumption is increased. It concluded that modified engine used during experiment has better performance at CR 12.4 with CNG.

VIII. AKNOWLEDGEMENT.

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