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The Study of Impact of Compression Ratio on the Performance and Emission Characteristics of DTSi Engine using Petrol and CNG as Fuel

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ABSTRACT

The digital twin spark ignition (DTSi) system is one of the most effective method used in SI engine in recent years. At present scenario, CNG is considered as one of the best alternate fuel for SI engine. It is a well-known fact that efficiency of SI engines mainly depends on the compression ratio (CR). The main purpose of the study is to find the effect of compression ratio (CR) on the performance and emission characteristics of four strokeDTSi engine using petrol and CNG as fuel. Theengine is tested with three CR that is 9, 9.5 and 10. For petrol,CR of 9.5 have shown better thermal efficiency, brake specific fuel consumption and volumetric efficiency, alsolowercarbon monoxide (CO) and unburnt hydrocarbon (HC) emission. It is seen that oxides of nitrogen (NO_X) emission found maximum for CR of 9.5 compared to other two CR. The CR of 10 resulted in better performance and lower emission when CNG is used as fuel with slight increase in NO_X emission.

1. Introduction

Effective utilization of products of petroleum is one of the basic need in the present condition due to rapid depletion crude oil reserves. This will encourage to look for better combustion system and alternative fuels which will result in better performance and lower tail pipe emission. In most of the SI engine petrol is the most commonly used fuel which has maximum problem with the exhaust emission especially in cities.

Natural gas is found to be one of the promising alternative fuel SI engine. Compared to petrol; CNG has higher octane number which makes it one of the better fuel for the SI engines [1]. CNG has benefits like lower fuel cost and cleaner exhaust emission. Chances of fouling of spark is less with CNG since it does not contain benzene in it. More over production cost of CNG is lower than that of petrol which makes it cheaper. It can also be considered as renewable since it has methane as its basic component which can be produced by anaerobic digestion. The main concern with CNG compared to petrol is its lower energy density which reduces the output powerand since it is a gaseous fuel, the volumetric efficiency of the engine reduces by a small value. The properties of the CNG and petrol [1]are mentioned in the Table1.

In spark ignition engine, decreases load results in reduced engine power. This leads to decreased initial and maximum pressure which intern results in dilution of incoming air-fuel mixture with the burnt gases. This phenomenon disturbs the development of flame kernel which results in increased the ignition delay period. By using 10-20% rich mixture (than stoichiometric) at part load condition, this problem can be overthrownbut it is difficult to evade the problem of after burning [2]. Thus deficient part load performance and requirement of enriched mixture are the major problems with the SI engine, also resultsfuel and there by increases the emission pollution in the exhaust. To overcome issues with the part load performance of SI engines, a numerous methods have been used to increase the lean burning limit. The different methods used includes usage of high power or longer duration discharges system, usage of flame and plasma jet ignition system [3] which initiates process of combustion with high temperature reacting jet, usage of multiple gap spark plug and multiple ignition system. Out of all these methods, multiple ignition system has its own importance since it attributes to the rapid and complete of combustion which considered to be the important need for the better performance in SI engine.

Table No.1 Properties of CNG and Petrol

Properties	**CNG**	**Petrol**
Octane number	120	85–98
Boiling Point, ^{0}C at 1 bar	-160	30-225
Lower heating value, MJ/kg	47.5	43.5
Stoichiometric air-fuel ratio(by mass)	17.2	14.6
Flammability limit (volume percent) in air	4.3-15.2	1.4-7.6
Flame propagation speed, m/s	0.41	0.5
Adiabatic flame temperature, ^{0}C	1890	2150

In multiple spark ignition engine ignition begins at two more points in the combustion chamber depending on number spark-plugs placed in the combustion chamber. If dual spark-plugs system is used then flame propagation starts at two different ignition centres there by reducing effective flame travel distance which intern help in improving knock resistance [1-3]. The twin plug concept is been considered for the studies for more than three decades. A number attempts have been made in the field of twin plug ignition engine in order to optimize the plug position and to show its benefits during part load operation, extending the tolerance exhaust gas recirculation and relatively clean combustion compared to single plug ignition system. Krishna PS et al., [1] have studied experimentally the influence of speed on the performance of 180cc DTSi engine and observed better engine performance in CNG than that of petrol and lower exhaust emission with CNG as fuel. . Narasimha B et al., [2] have conducted experiments on dual spark plug engine at different CR using petrol as a fuel and they found improvement in the part load performance and drop in CO and HC emission but slight rise NO_X emission in twin plug system in contrast to single plug. Narasimha B et al., [3] investigated the effect of ignition timing using petrol as fuel and concluded that simultaneous ignition results better performance and lower exhaust emission. Kuroda H., et al have conducted experimental study to optimize the shape of the combustion chamber and position of the spark-plug on a Nissan NAPS-Z engine to equalise the flame propagation of from dual plugs [4]. They also observed better fuel economy and reduced emission characteristics (reduced HC and NO_X) due to brisk combustion. Masonari H., et al [5] have conducted experiments on Nissan NAPS-Z to understand the effect of number of plugs an found similar results. Peter O W [6] have done experimental studies on the comprehend the relationship between spark plug location and rate of swirl and concluded that use of twin plug results in faster combustion than single plug along the common diameter near the mid radius position. Ramthilak A et al., [7] have done experimental studies on the DTSi engine and observed better fuel economy, better specific output, drivability, lower emission levels due to faster rate of combustion. It is also shown that twin ignition system results in improving unfavourable ignition condition like air-fuel mixture quality. [8-11]. Bozza F et al., [12] developed twin plug engine with variable valve timing and conducted experiments and the experimental values were compared with values of theoretical values which were developer using quasi dimensional model in order to optimise the VVT device position and spark advance. Ismail A et al., [13] developed a simulation of twin spark ignition based on thermodynamic cycle to evaluate the effect of effect of location of the spark plug.

From the previous researches it can be observed that twin ignition improves the rapidness of combustion which assists in achieving the complete combustion, thereby improving the engine performance and lower tail pipe emission. In the current work,impact of CR on the engine performance and exhaust emission is investigated.

2. Experimental set up:

A computerised single cylinder four stroke digital twin SI engine is used for conducting the experiments. Since CNG is used as a fuel, a standard

(LOVATO) CNG kit is used for feeding the CNG to the engine. Engine is loaded by using Eddy current dynamometer and for the effective cooling of the engine fan is used. The engine specifications are tabulated in table 2. To measure the performance parameters like fuel consumption, air flow rate, RPM and load, sensors are used. The signals generated by these sensors are read by the computer which is loaded with required software. These signals will be processed by the software and tabulates the performance parameters. The exhaust emission analysis is carried with help of NETEL gas analyser which measures carbon monoxide in percentage by volume, unburnt hydrocarbon and oxides of nitrogen emission in parts per million. Experiments were conducted for the compression ratios of 9, 9.5 and 10 at constant speed 2000 RPM at different loads using CNG and petrol.

Fig 1. Line diagram of engine test rig.

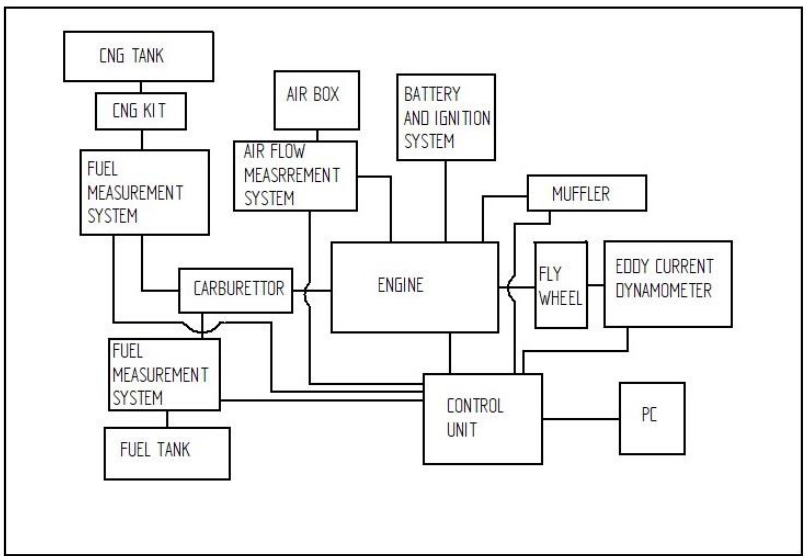

Table 2 Engine specifications

Type	Single cylinder four stroke DTSI engine (Bajaj)
Cylinder diameter	0.635 cm
Stroke length	0.654 cm
Cubic capacity	180 cc
Compression ratio	9.5
Rated power	16.8 bhp @ 8500 rpm
Cooling	Air cooled
Type Dynamometer	Eddy current

3. Results and discussions:

The performance parameters and emission characteristics were recorded by conducting experiments using engine test rig using CNG as fuel at compressions ratios of 9, 9.5 and 10 at 2000 RPM. The collected results are graphically presented from fig 1 to 7.

3.1Variation of Brake Thermal Efficiency (BTE):

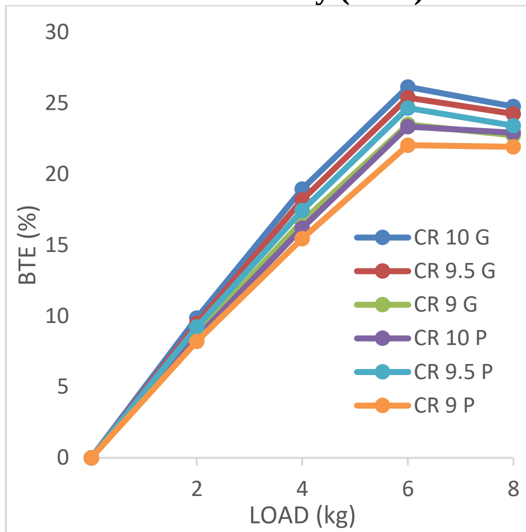

Fig 2 Comparison of brake thermal efficiency with load using petrol and CNG as fuel at different CR.

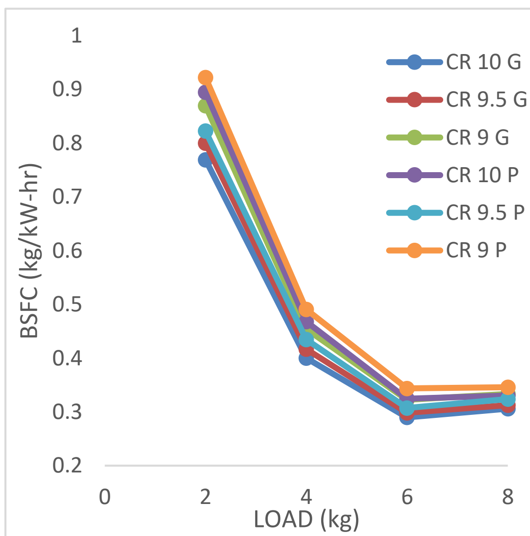

Fig 3 Comparison of brake specific fuel consumption with load forusing petrol and CNG as fuel at different CR

Fig 2 represents the variation of BTE with load, using petrol and CNGas fuel at different CR's. From the graphs it is clear that, the BTE increases with load reaches its maximum and then reduces for all compression ratios and both fuels. BTE is found maximum at

6kg load for all the CR's and both fuels. The BTE is found maximum for CR of 9.5 in case of petrol and 10 in case of CNG.

Theoretically, as the compression ratio increases the BTE should increase. For petrol, at lower CR of 9 efficiency is found low and higher CR of 10, knocking tendency found more severe with greater penalty on the BTE.In twin plug mode temperature rise inside the combustion chamber is more than that of single plug mode, this may attribute to the higher cylinder and outlet valve temperature with twin plug system because of rapid combustion, which promotes severe knocking in the engine cylinder [2]. Hence the intermediate compression ratio of 9.5shows best BTE and results optimum knock free CR for petrol [16]. The BTE increases with increase in compression in case of CNG. CNG has higher octane number compared to petrol [1,15,17] hence, results in knock free combustion even at higher CR.

3.2 Variation of Brake Specific fuel consumption (BSFC)

Fig 3. Represents the variation of BSFC with load. For all the CR's and for both fuels BSFC increases as the load increases and reaches its minimum and then increases. As BSFC is the mirror image BTE, it confirms with it. At CR of 9.5 BSFC is found minimum for petrol and for CNG at compression ratio of 10, this may be due to optimum turbulence and better mixing [1,16] of air and fuel resulting in efficientcombustion which intern results of optimum cylinder outlet valve temperature [2] which results knock free combustion.

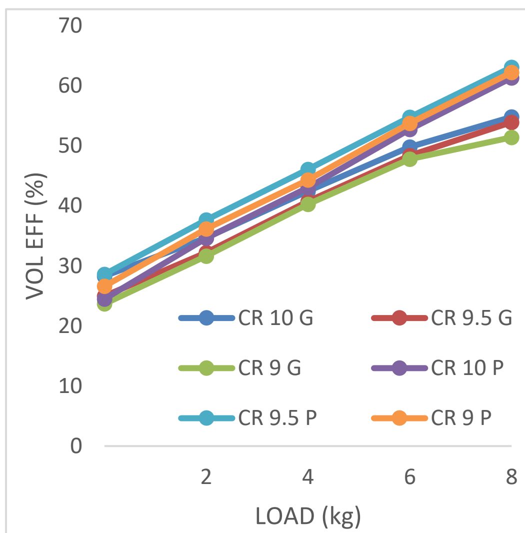

Fig 4 Comparison of volumetric efficiency with load using petrol and CNG as fuel at different CR

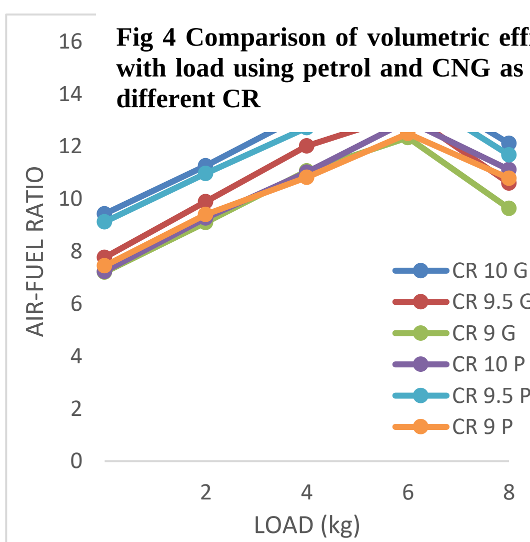

Fig 5 Comparison of Air-fuel ratio with load using petrol and CNG as fuel at different CR

3.3 Variation of volumetric efficiency

Fig 4 represents the variation of variation of volumetric efficiency with load. For all the CR's, as load increases the volumetric efficiency increases for both fuels. For petrol the volumetric efficiency is found better for CR of 9.5. At compression ratio of 9.5 which results in better thermal efficiency, the residual gas temperature [2] will be lower which results in better volumetric efficiency. The increased clearance volume in case lower compression ratio may be the reason for lower volumetric efficiency. At the CR of 10 volumetric efficiency is found lower due to higher residual gas and cylinder wall temperature.Since CNG is gaseous fuel compared to petrol volumetric efficiency [1] is lower. The volumetric efficiency is found maximum for the compression ratio of 10 due to lower clearance volume and lower residual gas temperature.

3.4 Variation of Air-fuel ratio

Fig 5 represents the variation of air-fuel ratio with load. The flow rate of air is controlled by butterfly valve and fuel flow rate with the help of carburettor characteristics along with CNG kit. It is clear from the graph that, the mixture is rich at lower load and with increase in load gradually shifting towards stochiometric strength [2] for all compression ratios. For petrol at CR of 9.5, the air-fuel ratiois found better and at CR of 10, air-fuel ratio is found better for CNG. This may be due lower fuel consumption and better utilisation of the air.

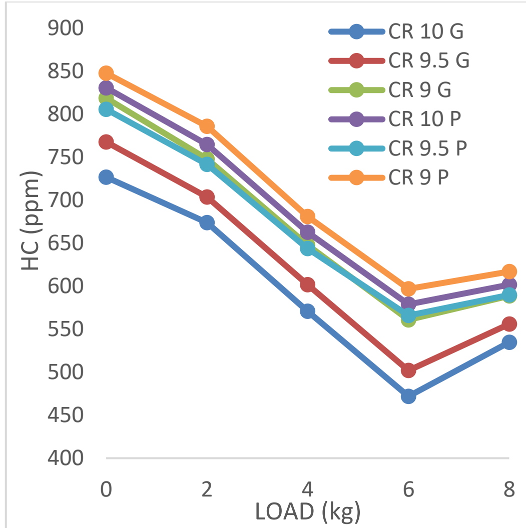

Fig 7 Comparison of unburnt hydrocarbon emission with load using petrol and CNG as fuel at different CR

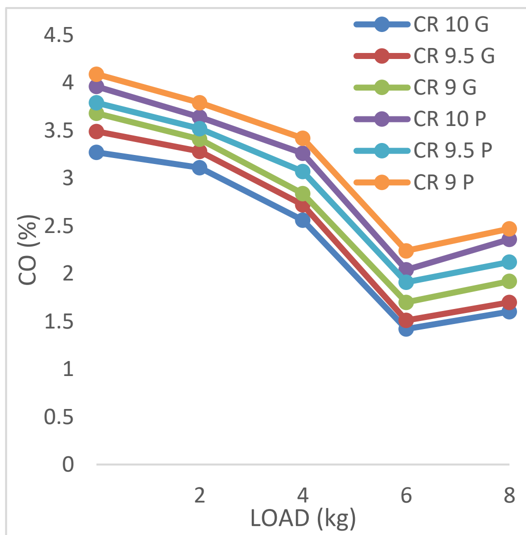

Fig 7 Comparison of Carbon monoxide emission with load using petrol and CNG as fuel at different CR

3.5 Variation of Unburnt Hydrocarbon (HC) emission

Fig 6 represents the variation of unburnt hydrocarbon with load for all three CR's. From the graph it is very clear that HC emission reduces as load and reaches minimum and then increases for both fuels. Since quench layer thickness increases at lower CR[2]HC emission increases. At higher CR tendency knocking may results in inefficient combustion, thereby increasing the HC emission in case of petrol.HC emission is found minimum at CR of 9.5

for petrol and CR of 10 for CNG. This is due to optimal cylinder temperature which results in decreases quench layer thickness, and also due to better mixing of the air and fuel. Since CNG is a gaseous fuel, it mixes better with air compared [1,15] to petrol and ensures lean mixture burning, [2]hence HC formation is lower compared to petrol.

3.6 Variation of Carbon Monoxide (CO) emission

Fig 7 represents the variation of carbon monoxide with load for all three CR's.The CO emission decreases as the load increases, arrives at minimum value and then increases again for all three CR's, and for the fuels. At CR of 9.5, due to better combustion results in higher combustion temperature [1] improves the oxidation CO, thus results in lower CO emissions. CO emission is found minimum at CR of 10. Because of lean mixture burning and higher combustion temperature due to increased compression ratio, CNG results lower CO emission compared to petrol.

3.7 Variation of Oxides of Nitrogen (NO_X) emission

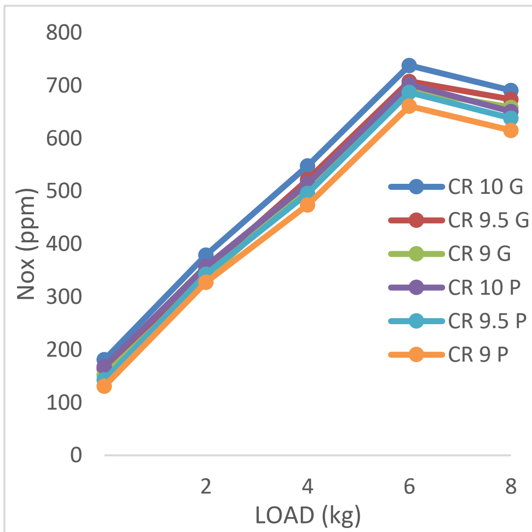

Fig 8 Comparison of NO_X emission with load using petrol and CNG as fuel at different CR

Fig 8 represents the variation of oxides of nitrogen with load for all three compression ratios and both fuels. As load increases the NO_X emission increases, reaches maximum then deceases. It is also clear from the observation that, NO_X found maximum for the compression ratio of 10 for both petrol and CNG. Higher temperature in the combustion chamber due to increased CR may be the main reason. At higher CR due to rapid combustion, the temperature in the combustion chamber of engine will increase which favours the formation of oxides of nitrogen [2]. At full load, because of decrease in air-fuel ratio the NO_X emission decreases.Compared to petrol NO_X emission if found maximum in case of CNG, the reason may be availability of oxygen due lean mixture burning [1]and also higher temperature due increased compression ratio.

4. Conclusion:

From the experimental studies the following conclusions can be derived:

- The BTE is maximum for the CR of 9.5 for petrol and 10 in case of CNG. This also agrees with BSFC, since fuel consumption is found minimum at CR of 9.5 for petrol and 10 in case of CNG.
- The volumetric efficiency is found maximum for the CR of 9.5 compared to two other compression ratios for petrol.The volumetric efficiency of CNG is slightly less in comparison to petrol and at CR of 10 better volumetric efficiency is observed.
- At the CR of 9.5, the CO and HC emissions are found minimum for petrol. CO and HC emissions are found minimum at compression ratio of 10 for CNG. In comparison petrol for all compression ratios, CNG resulted in lower CO an HC emission.
- The NO_X emissions are increased with in CR for both petrol and CNG. In case of CNG NO_X is found maximum compared to petrol.

It is experimentally found that there will be one optimalCR which results in better performance and lower exhaust emission and also nature of fuel has an impact on the CR of the engine.Higher CR's are not tried with CNG since automobile engine is used for experimentation which has a practical limitation.

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