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Comparative Analysis of a SI Engine using Petrol and CNG Fuel with and without Supercharger Review Study

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Abstract: The uses of engine-driven machines are increased and the air is polluted day by day. Thereby, substitution of natural gas (made by the country) in Petroleum would save more money (foreign currency spending), reduce air pollution and much more good benefits could be achieved. However, natural gas- driven engine could produce lesser power output in comparison with petroleum – driven engine. This problem can be solved by setting up the supercharger at the engine inlet that helped the engine to produce higher output, but reduce the air pollution. The comparison of performance of the petrol engine using the fuel of petrol and CNG as alternative fuel with and without supercharger are presented in this paper.

Keywords: Natural gas, Petroleum, Supercharger, Pollution, Engine.

1. INTRODUCTION

The number of cars in the world increases, especially in urban areas. The increase in pollution by hydrocarbons HC, CO_2, CO, and NO_x day by day. Gasoline is the main factor causing environmental pollution. Gasoline is very volatile fuel that contains a combination of hydrogen and carbon and if evaporated due to thermal effects at a higher speed, and then produce the carbon dioxide (CO_2) to pollute the atmosphere. Pollution has a significant impact on the environment and human health. Lead from gasoline not burned, carbon monoxide, compound containing gas and other gases polluting air deadly and harmful to humans, animals, and food crops [1].

To reduce its emissions characteristics, CNG is more suited for an engine internal combustion fuel. Therefore, it is necessary optimize CNG engine with high compression rate resulting in more power, less fuel consumption and emissions. CNG (compressed natural gas) is a mixture of hydrocarbons consisting of approximately 80-90%of methane.

Compressed Natural Gas is a gaseous form of natural gas and is mixture of hydrocarbons. It acts as an alternative fuel due to its substantial benefits compared to gasoline and diesel. It exists in the gaseous state at normal temperature and pressure. CNG is composed primarily of methane. It emits about 70% less carbon monoxide and has much less ozone-forming potential than standard petroleum gasoline. CNG is less expensive than gasoline. Heavy tanks are required to store it and the pressure required (200-300 bar).CNG is colorless, odorless, non-toxic, lighter than air and inflammable. The advantages of CNG are a unique combustion and suitable mixture formation. The engine operates smoothly with high compression ratios without knocking due to high octane number. It will lead to low exhaust emission and fueling operating cost, during lean burning conditions. It has a lower flame speed and causes high engine durability.

Compressed Natural Gas (CNG) engine can be divided into three main types; Dual Fuel Diesel-CNG, Gasoline-CNG and dedicated/mono fuel. The lack of engine performance is the main problem of CNG engine [2]. Its performance is lower than that of gasoline because of its losses in volumetric efficiency and low flame speed. This will cause the low engine power and torque. It needs to make design modification to achieve a faster burn to optimizing the engine performance [3] .The properties of petrol and CNG are listed in table 1&2.

TABLE I
THERMODYNAMICS PROPERTIES OF PETROL [3]

Stoichiometric ratio	14.2
Octane number	96
Higher heating value(MJ/kg)	45
Lower heating value(MJ/kg)	42.2
Molecular Weight(kg/kmol)	106.2

TABLE II
THERMODYNAMICS PROPERTIES OF CNG [3]

Stoichiometric ratio	15.7
Octane number	120
Higher heating value(MJ/kg)	50.3
Lower heating value(MJ/kg)	45.9
Molecular Weight(kg/kmol)	17.74

The researchers analyzed the comparison of CNG spraying machines with gasoline engines. Their energy can be reduced by about 10 to 15 percent. The two main reasons for this drop when injected into the CNG state are that some air channels may be used by this. And it reduces the volumetric efficiency which will cause the power reducing. Another reason is about air fuel ratio. The number is around 15.7 to 1 for gas and 14.2 to 1 for fuel. This factor has been identified as more necessary

for CNG engines in the air than gasoline engines with air. And the amount of additional air available for the engine can be obtained by overfeeding machines. If the amount of air pressure inlet in the engine can be increased, so it can also increase the amount of inlet air mass to the engine. Mass density of air entering the engine will cause the combustion to be complete which improves the thermal efficiency and therefore to compensate for CNG engines seems to be necessary. Until now, the supercharged engine optimization is done by the researches [4]. There are two methods for increasing the engine power. One of them would be to the proportion of fuel in fuel air mixture. This will increase the engine power but the fuel efficiency cost increase and pollution level also increase. The other method is by increasing the volume of air entering into the cylinder and increasing the fuel intake proportionately, this will increase the engine power the power and fuel efficiency without hurting the environment. In recent years, the motor vehicle industry aims at the small sized and high power density engine, while downsizing (small size and weight saving) and less air pollution. Supercharging is a process which helps to increase the suction of IC engines above the atmospheric pressure [5].

2. SPERCHARGING THEORY

The power output of the engine depends on the amount of air inducted per unit time, the degree of utilization of that air and the thermal efficiency of the engine. Increasing the engine speed or increasing the density of air at intake increase the amount of air inducted per unit time. The engine friction and bearing loads also increase and the volumetric efficiency decreases when the speed is increased. The method of increasing the inlet air density, called supercharging, is usually employed to increase the power output of the engine. This is done by supplying air at a pressure higher than the pressure at which the engine naturally aspirates air from the atmosphere by using a pressure boosting device called a supercharger. The power output can also be increased by increasing the thermal efficiency of the engine, say, by increasing the compression ratio. However, this increases the maximum cylinder pressure. The rate of increase of maximum cylinder pressure is less than rate of increase of break mean effective pressure in case of supercharged engine. This means that for a given maximum cylinder pressure more power can be obtained by increasing the compression ratio. The rate of increase of maximum temperature is also low in case of supercharging. This results in lower thermal loads [6].

The main objective of supercharging is to increase the amount of air per cycle. Due to access amount of air in charge (air-fuel mixture), permits the better combustion of fuel compare to aspirate. Thus the power output of the engine is increased. Purpose of supercharging is to raise the volumetric efficiency above that which can be obtained by normal configuration. The effect of supercharging on the performance of the engine are the power output, mechanical efficiency, volumetric efficiency and the fuel consumption [7].The PV diagrams of naturally aspirated &supercharged engines are presented as in figure.1.

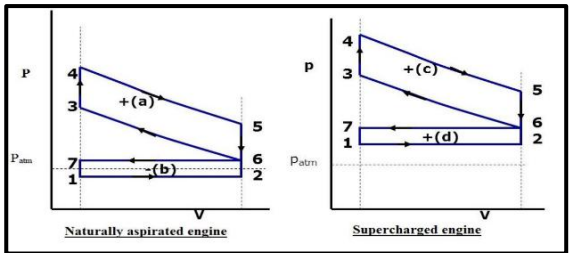

Fig.1. PV diagrams of naturally Aspirated &Supercharged engines

The power output of a naturally-aspirated engine can be increased by supercharging. It is necessary to make some modification of the engine for more suitable to supercharging. These modification include increase in the valve overlap period to allow complete scavenging of the clearance volume and increase in clearance volume by decreasing the compression ratio. The types of superchargers are Root Supercharger, Vane Supercharger and Centrifugal Supercharger. Two different types of supercharging methods are mechanical supercharging and turbocharging. The first limit is the knock for the SI engines and for CI engines the load and thermal stresses limits are reached first [8].

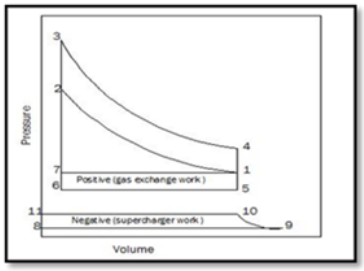

Fig. 2.Thermodynamics Analysis of Supercharged SI Engine [9]

TABLE III
VARIOUS PROCESS FOR THE SUPERCHARGED SI ENGINE

Process	**S. C. Engine**
Induction	7→1
Compression	1→2
Heat addition	2→3
Explosion	3→4
Heat rejection	4→1

A. Power Input for Mechanical Driven Supercharge [9]

Assuming adiabatic compression of air, the work done on the supercharger per kg of air is given by

$$\acute{\omega} = -\int \upsilon \, dp = h_2 - h_1$$
$$= C_p(T_1 - T_1) = C_p T_1 \left[\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

Where T_1 = initial temperature, p_1 = initial pressure, p_2 = delivery pressure.

And, with the isentropic efficiency of η_c

$$\acute{\omega} = \frac{C_p T_1}{\eta_c}\left[\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

Thus power required to drive the compressor is given by

$$= \frac{\dot{m}_a C_p T_1 \left[\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]}{60 \times \eta_c} \text{ kW}$$

Where $\dot{m}_a$ mass of air is supplied by supercharger in kg/min and $C_p$is specific heat of air in kJ/kg K.

3. THE COMPARISON OF THE PERFORMANCE OF THE PETROL FUELED GASOLINE ENGINE AND THE GASOLINE ENGINE USING THE CNG FUEL

Das and Reddy [10] conducted the experiment on CNG bi-fuel passenger car and predicted the engine performance, fuel consumption and emission to reduce system calibration time as well as the cost of testing. According to their result, the carbon monoxide (CO) on CNG is very lower compared to petrol engine.

E. Ramjee and K. Vijaya Kumar Reddy [3] did an experimental investigations on a single cylinder 4-stroke air cooled type Bajaj-Kawasaki petrol engine to compute performance and exhaust emissions of the test engine. All tests have been carried out under steady state conditions for both petrol and CNG fuels and the results have been compared. They found that for all range of speeds, the volumetric efficiency is reduced and various between 10-14%; except thermal efficiency the other performance parameters ,viz; BMEP, Torque, Power and BSFC are decreased for CNG fuelled engine compared to petrol fuelled engine; except NO_x the other emission characteristics such as CO, CO_2, and HC are decreased. The experiment tested at full load conditions and the various parameters of performance and emissions are calibrated.Fig.3 shows a graph plotted between volumetric efficiency and engine speed for both fuels.

From the graph, it is observed that the volumetric efficiency of CNG fuelled engine is lower than petrol engine, as the CNG engine occupies more volume of inlet air. The volumetric efficiency for CNG is decreases about 13.3% and it has occur at engine speed 4000 rpm and its average value is about 12.3% throughout the engine speed range. From the Fig. 4 and 5, it is learnt that the engine torque and brake power of CNG fuelled engine are considerably lower than that of petrol engine. This is due to lower volumetric efficiency of CNG fuelled engine.

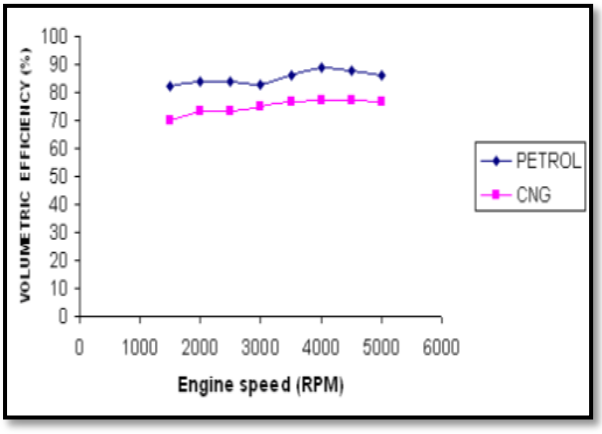

Fig. 3 Variation of volumetric efficiency and engine speed [3]

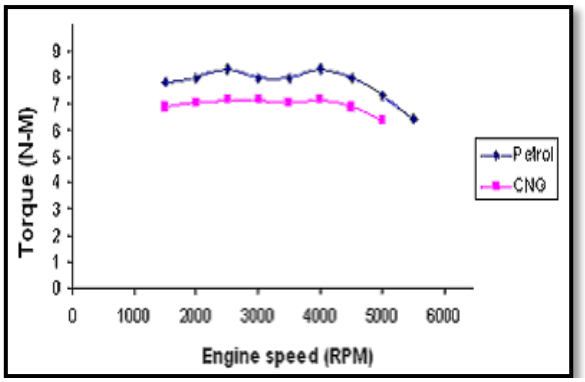

Fig. 4 Variation of Torque and engine speed [3]

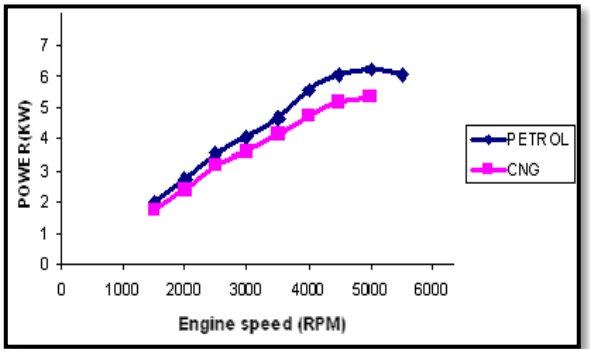

Fig.5.Variation 0f Power and engine Speed [3]

Munde Gopal G. [2] reviewed the research paper of compressed natural gas as an alternative fuel for spark ignition engine. According to this reviewed paper, it is studied that the compressed natural gas is a good alternative fuel for SI engine but some disadvantages observed from the studies of the various experimental results are: the engine thermal efficiency and exhaust gas temperature produced by the CNG burning is always higher than that of the petrol. CNG produces less 8 -16% of brake torque, brake power and BMEP compared to gasoline fuel due to reduced volumetric efficiency and lower flame speed of CNG. On average the reduction of CO, CO_2 and HC emission are 20 -98%, 8-20% and 40-87% respectively by CNG. Higher NO_x emission is the main emission concern for CNG as automotive fuel that can be reduced by increasing fuel density and blending small quantities of H_2.

Musthafah Mohd. Tahir [11] wrote the paper of Performance analysis of a spark ignition engine using compressed natural gas (CNG) as fuel. This study focused on the performance of CNG when used in a single cylinder SI engine. Based from the experiment in this study, compressed natural gas (CNG) produced low performance compared to liquid fuel (petrol). The power of CNG when compared to liquid fuel is reduced to about 18.5 %. The main reason for the lack of power when using CNG is because of the volumetric efficiency. According to this paper, the volumetric efficiency for this test engine is high when liquid fuel was used as the power source. However, when CNG was applied to this engine, it results low volumetric efficiency compare to liquid fuel. The lower volumetric efficiency is due to CNG physical properties, which is gas. During intake, CNG which consist of methane as the main particle does not produce a cooling effect during this condition. This result is due to the CNG is in the gas phase and it is vapor at ambient temperature.

4. COMPARISON OF THE PERFORMANCE OF THE PETROL FUELED GASOLINE ENGINE WITH AND WITHOUT SUPERCHARGER

Comparing performance characteristics of a gasoline and CNG engines and increasing volume efficiency and power using designed turbocharger was studied by Fathollah OMMI [4]. In this study, a one-dimensional model was used to model the XU-7 engine. After Gasoline and CNG engine model, the results of modelling was valid by using the results of engine dynamometer test and functional characteristics were compared between the two engines, and finally given the design parameters of the turbocharger, the engine system was selected for overfeeding. The results were presented in a CNG engine with a significant power reduction compared to gasoline engine. So two systems were modelled on CNG engine for solving this problem. The results were presented that using the designed turbocharger, the volumetric efficiency, braking torque and pressure inside the combustion chamber for overfeeding CNG engine have high level than natural breathing.

Pasala Venkata Satish[12] investigated the research of Performance Analysis of Supercharging a Single Cylinder SI Engine. A test engine, single cylinder 4 stroke air cooled petrol engine (3.7 kW) and vane type 50cc (driven by a belt and pulley) supercharger were set up for this experiment. From this literature the power and torque characteristic of the engine, for both the condition of the vehicle with & without a supercharger, is represented in graphical form.

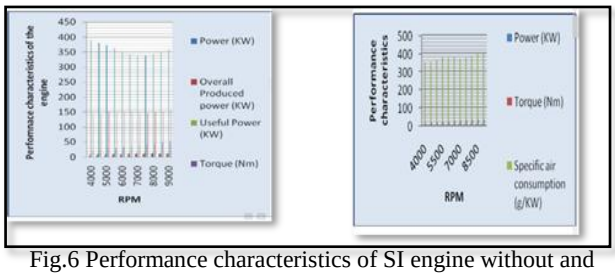

Fig.6 Performance characteristics of SI engine without and with supercharger [12]

From this research paper, it is concluded that the single cylinder SI engine with the supercharger which produce more horsepower on average about 150 % than the original SI engine.

Sujith G [13], did an experimental research of a 125cc Petrol engine with turbocharger. The experiment was carried out air cooled, 4 stroke single cylinder 124.7cc engine. Performance test was done to study and compare its performance under various loads with and without turbocharger. In this research work, it can be seen that the efficiency of the engine can be increased by the turbocharger. This method gives to increase the efficiency and at the same time to reduce the emission from the engine. And also this engine with turbocharger which have more brake thermal efficiency than the normal aspirated engine.

5. CONCLUSIONS

The main focus of this research review is to study the comparative analysis of CNG and Petrol as alternative fuel for SI engine with and without supercharger and as a result, the following conclusions were drawn as follows:

i. CNG has low volumetric efficiency and reduction in mechanical efficiency.
ii. CNG has no harmful effect on the engine and it is very adequate for S.I engines.
iii. CNG burns more completely than petrol and emits lower amounts of exhaust pollutants.
iv. CNG powered vehicles requires less maintenance, including fewer oil changes and less frequent spark plug replacement.
v. CNG has higher engine thermal efficiency and exhaust gas temperature.
vi. CNG produces less than of brake torque, brake power and BMEP compared to petrol due to reduced volumetric efficiency and lower flame speed of CNG.
vii. CNG has less brake specific fuel consumption (BSFC) compared to petrol.

After referring some of the literature research papers of the SI engine which set up supercharger, it can be seen that the performance of the vehicles improves in terms of power up to 10% to 15% and torque up to 5% to 10%. It also improves mechanical efficiency and volumetric efficiency due to pressurized air are present in the cylinder. The use of the supercharger helps in reducing the emission of carbon monoxide and other hydrocarbons. Supercharger unit can be installed as detachable device.

From the study of this review paper, gas- driven engine could produce lesser power output in comparison with petroleum and the petroleum –driven engine with the supercharger gives more power output than the normal aspirated engine. So the problem (to detect from the power downgrade by using CNG fuel) is solved by setting up the supercharger at the engine inlet to the compressed natural gas-driven engine that helped the engine to produce higher output, but reduce the air pollution.

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