A Review on Effect of CNG Substitution on Performance and Emission of Diesel Piloted Dual Fuel Engine

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Abstract— CNG is well known for replacement of Fossil Fuel and lower Emission. The project Aim is enable use of Natural gas at higher compression ratio. It can be achieved by Dual Fuel Engine. The research on Dual Fuel is carried out to reduce Dependence of CI engine on Diesel Fuel. Natural gas is used as main Fuel and Diesel is used as pilot fuel to initiate combustion. According to literature survey, Performance and Emission of Dual Fuel engine varied according to the Amount of CNG. So the substitution is varied in order to achieve better performance and reduce emission. In this work, Effect of CNG substitution on Performance and Emission is studied and compared with conventional Diesel Engine.

Key words: Dual Fuel Engine, CNG

I. Introduction

A. *Dual Fuel Engine*

In some diesel engine[11], gaseous fuel is used for partial replacement of diesel. The engine using this technology is known as DUAL FUEL ENGINE. A dual fuel engine is based on a traditional diesel engine. When the engine is operating in dual fuel mode, gaseous fuel is introduced into the intake system. The air-to- gas mixture from the intake is drawn into the cylinder, same way as in a spark-ignited engine, but with a leaner air-to-fuel ratio. Just before the compression stroke, diesel fuel is injected, same way as in a traditional diesel engine. The diesel fuel gain its auto ignition temperature and combustion starts which causes the mixture to burn. A dual fuel engine can be operate either fully diesel fuel mode or the substitution mixture of diesel and Gaseous Fuel. Dual fuel engines have same performance of power density, torque curve and transient response as the base diesel engine does. This technology can be used for diesel-CNG dual fuel engines. Using natural gas in diesel engine provides both economic and environmental benefits. CNG costs 15%-40% less than gasoline or diesel. [11]

B. *CNG*

Natural gas is a potential alternative fuel to engine in the current and future, because it has the higher efficiency and lower emission. Besides as a clean burning fuel, natural gas has the other advantage such as large reserve. The reasons for this is, CNG has its main composition methane (CH_4) for about 90%. Which is has been known that the higher H fraction in engine fuels and lower CO_2, that cause the lower dangerous gas emissions from the combustion. Second, the density of CNG is lower than fresh air, therefore, in case of leakage both in the tank and in the fuel line system the CNG will evaporate to the top of the air quickly. Third, due to the CNG is in the form of gas, hence, it will not require to be evaporated first like gasoline before filled into the chamber. This can reduce the problem related to the cold start in the low temperature season and eliminate excessive emission caused by the rich air-fuel mixture when the engine is started. Natural gas combustion is clean and emits less CO_2 compared to other fossil fuels, which makes it favorable for utilization in internal combustion engines (ICEs).

II. Existing Literature

Peter L. Mtui[1] have done Numerical modeling by varying engine load conditions from 100% to 77%, while with increasing the quantity of natural gas substitution from 0% to 80%. Capacity of engine to give highest output, bsfc, emission was observed to be changed with substitution. Results shows that up to 80% natural gas substitution is possible over wide range of engine load conditions at higher engine loads. However, for 77% engine load conditions engine performance deterioration above 60% natural gas deterioration, of particular, was higher BSFC and excessive CO emissions. Compared with straight diesel, the in-cylinder NOx formation was significantly reduced by as the quantity of natural gas substitution was increased. For example, NOx can be reduced by 50% when engine is at 80% engine load and fuelled with 60% natural gas substitution.

Md. Ehsan and Shafiquzzaman Bhuiyan[2] observed that It was possible to run the engine in dual fuel mode with various maximum diesel replacement levels by natural gas, at different power levels. The replacement could be as high as 90% of the diesel used up to about 75% of the actual capacity, this was limited to 88% diesel replacement at about 90% of the actual capacity and only about 69% diesel replacement at the actual full load. At each load the diesel replacement is again limited by the knocking tendency in dual fuel mode.

Y.E. Selim Mohamed[3] investigated comparison of three gaseous fuel LPG, CNG and methane and found early knocking in LPG and followed by CNG and Methane has lowest knocking, because LPG has lowest auto ignition temp and Methane has highest auto ignition temperature. . They have shown that the ignition delay of the pilot Diesel was increased when natural gas is present in mixture. Their data show that when 2% methane is present in the intake air it will doubles the ignition delay of the Diesel fuel. The dual fuel engine that utilizes methane will produces higher power and efficiency than that using natural gas, followed by LPG. Increasing the engine speed or load increases the thermal efficiency in the dual fuel engine mode. Increasing the engine speed reduces the combustion noise for the dual fuel engine. Advancing the pilot fuel injection timing reduces the torque output, reduces the thermal efficiency and increases the maximum pressure and also maximum pressure rise rate. Increasing the quantity of pilot fuel increases the torque output, thermal efficiency and maximum pressure for the three gases, yet it reduces the combustion noise for the three gases.

Tala1 F. Yusaf and Mushtak Talib[4] observed that dual-fuel system performed well under moderate to high loads, and operated at equal or better fuel efficiencies compared to pure diesel under these conditions. Under light load operation, the dual-fuel system suffered a loss of fuel efficiency and increased CO emissions relative to the diesel system. The level of CO2 for the CNG – diesel engine was lower than that for the diesel operation as expected based on fuel composition considerations. Measurements also showed that excess of O2 decreased as the engine speed increases. The excess oxygen was almost the same for both diesel and dual-fuel systems Based on the results of this study, the use of CNG in diesel engines appears beneficial because emissions can be reduced without any compromise in efficiency.

R.R. Saraf[5] calculate the Value of lambda for each percentage substitution of diesel by using Brettschneider equation. It was observed that dual fuel operation has lower NO_x and soot emissions compared to normal diesel operation. It was observed that peak cylinder pressure is less and brake specific fuel consumption is more in dual fuel operation as compared to a normal diesel operation. At idling and light load conditions substitution rate of natural gas is low and diesel fuel consumption is higher. At high speeds or loads substitution rate of natural gas is higher and results in lower emissions. It was observed that minimum value of lambda was 1.228287 and maximum value was 1.484604.Lambda is leanest at 60 % of CNG substitution. Lambda shows increasing and decreasing trend against % of substitution and speed. Torque decreases as speed and percentage of substitution increases. Power increases with speed and percentage of substitution. As lambda increases, torque decreases initially and then it increases.

Mayank Mittal[6] showed that NOx emission was reduced at all operating range of loads under dual fuel operation compared to diesel operation. At light load condition the mixture of natural gas-air is very lean, which complicates flame propagation throughout the combustion chamber from the pilot ignition. However, gaseous fuel utilization improves at higher loads due to higher charge temperature. Therefore, HC emissions are reduced with increased load. It is evident that CO emissions under dual fuel operation are considerably higher than that of diesel operation. HC and CO emissions were increased under dual fuel operation, but their concentrations were considerably reduced with help of oxidation catalyst. It was found that soot and particulate matter were increased under dual fuel operation as compared to diesel operation. The gaseous fuel utilization improves at moderate and high loads due to higher charge temperature, and hence CO emissions are reduced at higher loads compared to light load. NOx emission is reduced at all operating loads under dual fuel operation compared to diesel operation. It is to be noted that under dual fuel operation, gaseous fuel replaces part of the intake air and hence oxygen concentration decreases compared to diesel operation.

L. Tarabet[7] investigate how eucalyptus biodiesel and natural gas in dual fuel combustion mode can reduce exhaust emissions and improve combustion performance. The combustion analysis has shown that biodiesel used as pilot fuel have same pressure time history, with highest peak, as diesel fuel in conventional and dual fuel combustion modes. The performance and pollutant emission results show that, in comparison of diesel fuel in dual fuel mode, the use of eucalyptus biodiesel as pilot fuel reduces the high emission levels of unburned hydrocarbons(HC), carbon monoxide(CO) and carbon dioxide(CO2) particularly at higher engine loads. However it has disadvantage of an increase in the brake specific fuel consumption (BSFC) and the nitrogen oxide (NO_x) emissions, that is due to the lower calorific value and the oxygen presence in the molecule of the eucalyptus biodiesel, respectively. Biodiesel has good ability of ignition in engine due to its relatively high catane number compared to that of conventional diesel fuel engine. The ignition delay for NG–biodiesel indicates a shortened nature compared to diesel fuel in conventional and dual fuel modes due to the high cetane number of biodiesel. The dual fuel mode of combustion exhibits a similar pollutant emissions nature for both pilot fuels. The concentrations of UHC and CO emissions are considerably higher for the dual-fuel mode with either pilot fuel than for conventional diesel fuel mode under all operating conditions. Up to 70% of engine full load, the dual fuel mode results in lower NOx emissions than that of conventional diesel fuel mode. Also, dual fuel mode for both pilot fuels exhibits lower levels of particulate matter(PM) emissions particularly at high engine load due to the higher combustion temperature and rapid flame propagation, as a consequence of the combustion improvements. Overall, it concluded that dual fuel combustion using natural gas as a supplement for eucalyptus biodiesel is an good technique for remedying to the deficiencies of using diesel fuel in conventional and dual fuel modes such as UHC, CO, CO2 and particulate matter emission levels. This is particularly true at high engine load.

Abhishek Paul[8] found that the increased percentage of ethanol and biodiesel in the pilot fuel and found an increase in the brake thermal efficiency of the engine. In this study, the NOx emission was also observed to decrease with a appropriate increase in the percentages of ethanol and biodiesel in the pilot fuel. The hydrocarbon emission from the engine was observed to increase with the CNG substitution in Diesel operation. The hydrocarbon emission was observed to decrease with the addition of ethanol to the pilot fuel. The pilot operation of the D45E15B40 and D30E20B50 blends is found to be useful in improving engine performance because of improvement in the brake thermal efficiency. However, due to the reduced calorific value of the blends, the pilot fuel flow is observed to increase at some margin for the mentioned Diesel ethanol biodiesel blends. The blends are found to decrease the NOx emission of the engine, and the major decrease is found with the D30E20B50 blend pilot operation. The CNG dual fuel operation with the blends is also found to produce less CO emissions than the CNG-Diesel dual fuel operation. The hydrocarbon emission from the engine with the CNG-Diesel dual fuel mode operation is found to increase with the increase in CNG injection durations.

Jie Liu[9] NO formation region follows the development of the high temperature field, due to the combustion of the pilot diesel. At low engine speed, the piston crevices are mainly responsible for the creation of the unburned CH4 emissions. However, at high engine speed, bulk gas partial oxidation in the cylinder center region is responsible CH4 emissions. The flame quench zone in the squish volume close to the cylinder walls is the main source of the CO emission at lower engine speed. However, the bulk gas partial oxidation zone in the cylinder center region is major source of the CO emission at high engine speed.

Kyunghyun Ryu[10] show that performance can be optimized for biodiesel CNG dual fuel combustion by advancing the pilot injection timing at low loads and delaying the injection timing at high loads. Ignition delays are reduced with the increased engine load. BSFC of biodiesel–CNG Dual fuel combustion improves with advanced pilot injection timing at low load and with delayed pilot injection timing at full load. Smoke is decreased and NOx is increased with advanced pilot injection timing in the biodiesel–CNG Dual fuel combustion. Biodiesel–CNG Dual Fuel Combustion results in relative high CO and HC emissions at low load conditions due to the low combustion temperature of CNG but no notable nature of HC emissions with variations of pilot injection timing were discovered.

III. Conclusion

After comprehensive study of existing literature in dual fuel performance, following conclusions have been made:

- CNG has a high octane number, which is considerably higher than that of gasoline; consequently, CNG vehicle is more efficient. Due to the higher octane number CNG allows higher compression ratios and improved thermal efficiency, reducing carbon dioxide emissions.
- Capacity of Dual Fuel engine to give highest output, bsfc , emission is changed with substitution.
- Maximum possible substitution of CNG is noticed to be varied according to the load on Engine. At each load the diesel replacement is limited by the knocking tendency in dual fuel mode.
- Dual fuel mode exhibits lower levels of particulate matter emissions particularly at high engine load because of the higher combustion temperature and rapid flame propagation, as a consequence of the improvements in combustion.
- NOx emission of Dual Fuel Engine is quite lower than that of Diesel Engine.
- HC and CO emissions were increased under dual fuel operation, but their concentrations were considerably reduced with oxidation catalyst.

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