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A Technical Review on the Impact of Switching to CNG on the Emissions and performance of Diesel-Piloted Dual Fuel Engines

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Abstract

It is commonly known that CNG reduces emissions and can replace fossil fuels. The project's goal is to increase the compression ratio for the use of natural gas. An engine with dual fuel can accomplish that. The goal of dual fuel research is to lessen the reliance of CI engines on diesel fuel. Diesel is used as a pilot fuel to start the combustion of natural gas, which serves as the main fuel. A review of the literature revealed that the amount of CNG used affected the dual fuel engine's performance and emissions. Therefore, different substitutions are used to improve performance and lower emissions. This study examines the impact of switching to compressed natural gas (CNG) on emissions and performance, comparing it to traditional diesel engines.

Keywords : Dual Fuel Engine, CNG

INTRODUCTION

A. Dual Fuel Engine

Gaseous fuel is used in certain diesel engines to partially replace diesel. The term "DUAL FUEL ENGINE" refers to the engine that uses this technology. A conventional diesel engine is the foundation of a dual fuel engine. Gaseous fuel enters the intake system when the engine is running in dual fuel mode. Similar to a spark-ignited engine, the air-to-gas mixture from the intake is drawn into the cylinder with a reduced air-to-fuel ratio. Diesel fuel is injected just prior to the compression stroke, exactly like in a conventional diesel engine. The mixture burns when the diesel fuel reaches its auto ignition temperature and begins to burn. An engine that runs on two fuels can run entirely on diesel or run on a combination of diesel and gaseous fuel. The power density, torque curve, and transient response of dual fuel engines are identical to those of the base diesel engine. Dual fuel engines that run on both diesel and CNG can use this technology. There are advantages for the environment and economy when using natural gas in diesel engines. CNG is 15%–40% less expensive than diesel or gasoline. [11]

B. CNG

Because it is more efficient and produces fewer emissions than other fuels, natural gas has the potential to replace engine fuel in the present and the future. Natural gas has additional benefits in addition to being a clean-burning fuel, like a big reserve. The primary component of CNG is methane (CH_4), which accounts for roughly 90% of its composition. It is well known that lower CO_2 and a higher H fraction in engine fuels result in less harmful gas emissions during combustion. Second, because CNG has a lower density than fresh air, it will quickly evaporate to the top of the air in the event of a leak in the fuel line system or tank. Third, since CNG is a gas, it won't need to be evaporated first like gasoline before being poured into the chamber. By doing this, you can lessen the issue of cold starts during the winter and get rid of the excess emissions that come from the engine's rich air-fuel mixture when it starts. Natural gas is a good fuel to use in internal combustion engines (ICEs) because it burns cleanly and produces less CO2 than other fossil fuels.

EXISTING LITERATURE

Peter L. Mtui[1] have performed numerical modeling by increasing the amount of natural gas substitution from 0% to 80% while changing the engine load conditions from 100% to 77%. It was noted that engine capacity to produce the maximum output, bsfc, and emission changed with substitution. The results indicate that at higher engine loads, natural gas substitution is possible up to 80% of the time under a wide range of engine load conditions. Higher BSFC and excessive CO emissions were, however, the engine performance deterioration above 60% natural gas deterioration for 77% engine load conditions. As the amount of natural gas substitution was increased, the in-cylinder NOx formation was significantly reduced when compared to straight diesel.

It was noted by Md. Ehsan and Shafiquzzaman Bhuiyan[2] that the engine could be operated in dual fuel mode at different power levels and with different maximum levels of natural gas replacement for diesel. This was limited to 88% diesel replacement at about 90% of the actual capacity and only roughly 69% diesel replacement at the actual full load. The replacement could go as high as 90% of the diesel used up to about 75% of the actual capacity. The dual fuel mode's tendency to knock limits the diesel replacement at each load.

Y.E. Selim Mohamed[3] compared three gaseous fuels: methane, CNG, and LPG. He discovered that methane has the lowest knocking while LPG has the highest auto ignition temperature. LPG exhibits the lowest knocking, followed by CNG. They have demonstrated that the presence of natural gas in the mixture lengthens the pilot diesel's ignition delay. According to their data, the ignition delay of diesel fuel doubles when there is 2% methane present in the intake air. The methane-fueled dual fuel engine outperforms the natural gas and LPG-fueled engines in terms of power and efficiency. In the dual fuel engine mode, the thermal efficiency rises with increasing engine speed or load. For the dual fuel engine, increasing engine speed lowers combustion noise. Pilot fuel injection timing advancement results in decreased torque output, decreased thermal efficiency, increased maximum pressure, and increased maximum pressure rise rate. The torque output, thermal efficiency, and maximum pressure of the three gases increase with an increase in pilot fuel quantity, but the noise produced during combustion decreases.

Tala1 F. Yusaf and Mushtak Talib[4] found that the dual-fuel system outperformed the pure diesel under moderate to high load scenarios, operating at fuel efficiencies that were on par with or higher. Compared to the diesel system, the dual-fuel system had higher CO emissions and less fuel efficiency during light load operation. Based on factors related to fuel composition, it was expected that the CO2 level for the CNG-diesel engine would be lower than for the diesel operation. Additionally, measurements revealed that as engine speed increased, the excess O2 decreased. The excess oxygen in the dual-fuel and diesel systems was nearly equal. The study's findings suggest that using CNG in diesel engines can lower emissions without sacrificing engine performance, which is advantageous.

Using the Brettschneider equation, R.R. Saraf[5] determined the value of lambda for each percentage of diesel substitution. Comparing dual fuel operation to regular diesel operation, it was found that the former produces less NOx and soot emissions. It was found that when using dual fuel instead of regular diesel, there is a decrease in peak cylinder pressure and an increase in brake-specific fuel consumption. Natural gas substitution rate is low and diesel fuel consumption is higher during idling and light load situations. Natural gas has a higher substitution rate and produces fewer emissions at high loads or speeds. Lambda was found to have a minimum value of 1.228287 and a maximum value of 1.484604.Lambda substitutes 60% of CNG and is the leanest. In relation to speed and substitution percentage, lambda exhibits an increasing and decreasing trend. As speed and substitution percentage rise, torque falls. Power rises as substitution percentage and speed do. Torque first decreases and then increases as lambda increases.

In comparison to diesel operation, Mayank Mittal's research [6] demonstrated that NOx emissions were lower under dual fuel operation across the whole operating load range. The natural gas-air mixture is extremely lean under light load conditions, which makes it more difficult for the flame to spread from the pilot ignition throughout the combustion chamber. However, because of the higher charge temperature, gaseous fuel utilization improves at higher loads. Thus, as the load increases, HC emissions decrease. It is clear that when using dual fuel, CO emissions are significantly higher than when using diesel. Dual fuel operation resulted in higher emissions of CO and HC, but the oxidation catalyst helped to significantly lower their concentrations. It was discovered that when dual fuel operation was used instead of diesel, there was an increase in soot and particulate matter. Because of the higher charge temperature, gaseous fuel utilization improves at moderate and high loads, resulting in lower CO emissions at higher loads relative to light loads. When using dual fuel instead of diesel, NOx emissions are decreased at all operating loads. It should be mentioned that, in contrast to diesel operation, the oxygen concentration falls when operating with dual fuel because gaseous fuel partially replaces the intake air.

L. Tarabet[7] looks into the possibilities of using natural gas and eucalyptus biodiesel in a dual fuel combustion mode to lower exhaust emissions and enhance combustion efficiency.According to the combustion analysis, in both conventional and dual fuel combustion modes, biodiesel used as pilot fuel has the same pressure time history and highest peak as diesel fuel. The performance and pollutant emission results demonstrate that using eucalyptus biodiesel as pilot fuel lowers the high emission levels of unburned hydrocarbons (HC), carbon monoxide (CO), and carbon dioxide (CO2), especially at higher engine loads, when compared to diesel fuel in dual fuel mode. Nevertheless, because of the eucalyptus biodiesel's lower calorific value and the oxygen present in its molecules, it has the drawback of increasing brake specific fuel consumption (BSFC) and nitrogen oxide (NOx) emissions. Because it has a higher catane number than conventional diesel fuel, biodiesel can ignite more easily in an engine. Because of the high cetane number of biodiesel, the ignition delay for NG-biodiesel in conventional and dual fuel modes is shorter than that of diesel fuel. For both pilot fuels, the dual fuel mode of combustion shows comparable pollutant emissions. Under all operating conditions, the dual-fuel mode using either pilot fuel has significantly higher concentrations of UHC and CO emissions than the conventional diesel fuel mode. The dual fuel mode produces lower NOx emissions than the conventional diesel fuel mode up to 70% of engine full load.

Additionally, as a result of the combustion improvements, dual fuel mode for both pilot fuels shows lower levels of particulate matter (PM) emissions, especially at high engine load due to the higher combustion temperature and quick flame propagation.. Overall, it was found that the drawbacks of using diesel fuel in conventional and dual fuel modes, such as UHC, CO, CO2, and particulate matter emission levels, could be addressed by dual fuel combustion using natural gas as a supplement for eucalyptus biodiesel. This is especially valid with a high engine load.

Abhishek Paul[8] discovered that the engine's brake thermal efficiency increased with the percentage of ethanol and biodiesel added to the pilot fuel. In this investigation, it was also found that when the proportions of ethanol and biodiesel in the pilot fuel were appropriately increased, the NOx emissions decreased. When CNG was used instead of diesel when operating the engine, there was an increase in the engine's hydrocarbon emissions. When ethanol was added to the pilot fuel, a decrease in hydrocarbon emissions was observed. The D45E15B40 and D30E20B50 blends' pilot operation is found to be beneficial for enhancing engine performance due to an increase in brake thermal efficiency. Nonetheless, for the aforementioned Diesel ethanol biodiesel blends, it is observed that the pilot fuel flow increases somewhat as a result of the blends' lower calorific value. It is discovered that the blends reduce the engine's NOx emissions; the D30E20B50 blend pilot operation results in the largest reduction. It is also discovered that compared to the CNG-Diesel dual fuel operation, the CNG dual fuel operation with the blends emits fewer CO emissions. When using the CNG-Diesel dual fuel mode, it has been observed that the engine's hydrocarbon emissions rise as the CNG injection duration increases.

Liu Jie [9] As a result of the pilot diesel burning, a high temperature field develops, followed by the NO formation region. The unburned CH4 emissions are mostly produced by the piston crevices at low engine speeds. On the other hand, CH4 emissions at high engine speeds are caused by partial oxidation of bulk gas in the cylinder center region. At lower engine speeds, the primary source of CO emissions is the flame quench zone in the squish volume near the cylinder walls. Nevertheless, at high engine speeds, the main source of CO emissions is the bulk gas partial oxidation zone in the cylinder center region.

According to Kyunghyun Ryu's research [10], by advancing the pilot injection timing at low loads and delaying the injection timing at high loads, biodiesel CNG dual fuel combustion performance can be optimized. The increased engine load decreases ignition delays. When the pilot injection timing is advanced at low load and delayed at full load, the biodiesel-CNG dual fuel combustion's BSFC improves. With advanced pilot injection timing in the biodiesel–CNG dual fuel combustion, smoke is reduced and NOx is increased. Because of the low combustion temperature of CNG, biodiesel–CNG dual fuel combustion produces relatively high CO and HC emissions at low load conditions; however, no discernible changes in HC emissions were found in relation to pilot injection timing variations.

CONCLUSION

Following an extensive analysis of the body of research on dual fuel performance, the following conclusions have been drawn:

- The octane number of CNG is significantly higher than that of gasoline, making CNG vehicles more efficient. CNG emits less carbon dioxide because its higher octane number permits higher compression ratios and better thermal efficiency.

- The Dual Fuel engine's maximum output, BSP, and emission can be altered through substitution.
- It has been observed that the engine load affects the maximum amount of CNG replacement that can be made. The dual fuel mode's tendency to knock limits the amount of diesel that can be replaced at each load.
- As a result of the improvements in combustion, dual fuel mode exhibits lower levels of particulate matter emissions, especially at high engine load due to the higher combustion temperature and rapid flame propagation.
- Compared to diesel engines, dual fuel engines emit significantly less NOx.
- Dual fuel operation resulted in higher emissions of CO and HC, but oxidation catalyst significantly decreased their concentrations.

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