Combustion Characteristics and Emissions of a Direct-Injection Diesel Engine Fueled with GTL fuel blends

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I. Introduction

Gas to Liquids (GTL) is one of clean alternative fuels which loosely defined terms that is generally used to describe the chemical conversion of natural gas to some type of liquid products. As such, it excludes the production of liquefied natural gas (LNG), but includes the conversion of gas to methanol, liquid fuels, and petrochemicals, being the most common applications. In other words, Gas to liquids (GTL) technology is used to convert a carbon containing feedstock such as natural gas, to synthetic diesel fuels and further developed by oil companies. Fewer studies investigated the use of GTL diesel with the existing diesel engines to study the effect of using this new alternative fuel on the efficiency and emissions in these engines. Hence, the objectives of this study are to investigate the behavior of the GTL – diesel fuel blends in context of different combustion characteristics, engine performance and emissions. It is expected that the outcomes of this study will shed further light on GTL diesel fuel as a clean alternative fuel.

II. Experimental Methods

The experiments were carried out on a T85D single cylinder, four stoke, water cooled, direct injection, compression ignition engine attached to DIDACTA ITALIA engine test bed. An electric dynamometer with motor and a load cell was coupled to engine. Engine specifications are shown in Table.1. Two fuel tanks were assembled in the test bed; one tank was used for convention diesel fuel and the other was used for GTL Diesel. The properties of the used fuel are mentioned in Table.2. It can be observed that the GTL fuel has a lower density and viscosity and high cetane number in comparison with conventional diesel fuel as demonstrated in Table. 2. All these properties are in favor of improving fuel evaporation and mixing with air, which lead to better combustion characteristics.

The engine test bed and the measuring devices are shown schematically in Fig. 1. The in-cylinder pressure was measured by using a water cooled piezoelectric pressure transducer AVL QH 33D which was mounted flush at cylinder head and connected via AVL charge amplifier. The output signal was displayed on Instek GDS-3152 Digital Storage Oscilloscope with 150 MHz sampling rate. Then, the data was transferred to a laptop which saved for further analysis. The crank shaft position was measured using a digital shaft encoder.

The engine speed was measured by using a speed tachometer that used the pulse counting principle to detect the crank shaft speed, while the fuel flow rate was measured by using a calibrated burette and a stop watch. The engine torque was measured by using a load cell. Engine NO_x emission was measured by a long life electrochemical sensor at NOVA-7465PK portable engine exhaust emission analyzer .This electrochemical sensor has anodes, cathodes and suitable electrolyte sealed inside it which, when exposed to gasses, produces a small output current. This output is directly proportionally to the amount of NO gas in the sample. A Pre-Amplifier board directly mounted on the top of the sensor boosts the small signal and converts it to an output of 1 mV per PPM .This output is then sent the main microprocessor board, corrected for the calibration then displayed on the LCD display meter. The resolution of the NOx sensor is ± 1 PPM. The test rig is also equipped with a type-K thermocouples to measure air inlet manifold, engine cooling temperatures and exhaust temperatures which were mounted at relevant points. Normal engine test bed safety features are also included .Atmospheric conditions (temperature and pressure) were monitored during the tests.

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III. Results and Discussion

In this section, a comparison between the new manifold designs and the standard manifold of the engine in terms of engine performance and emissions is presented. A number of experiments have been conducted when the engine runs at different loads and different speeds. In addition, the results of using conventional diesel, GTL and 50%-50% blends of both fuels will be presented to show the fuel effect on the above mentioned parameters.

A. Engine Performance

Figure 2. Shows the effect of in cylinder pressure change with crank angle for the diesel at 1700 rpm with variable loads fuels .It was obvious when load increases, the pressure increases. The maximum pressure occurs 18.7 ATDC at no load condition .As load increases the combustion duration increases which lead to long the ignition delay period. It can be observed from Fig. 3 that the maximum pressure values of both fuels and their blends are comparable over the whole range of operation. This proves the suitability of the combustion characteristics of GTL fuel and its blends with conventional diesel to be used with the existing engine designs.

One of the important performance parameters of internal combustion engines is Brake thermal efficiency which indicates how energy conversion added by heat is transferred into a net useful output work. The engine brake thermal efficiency, not shown here, increases with increasing of load. In case of variant load constant speed at 1700 rpm operation condition, the efficiency of GTL fuel was slightly lower than conventional diesel and 50% -50% blend with about (1.5 % - 8%) and (1.3% -7.75 %) compared with diesel, respectively. Higher cetane number, Low viscosity and density of GTL fuel properties leads to efficiency degradation compared with diesel fuel. On the other hand, the engine brake thermal efficiency decreases with increasing of speed. In case of constant load variable speed operation condition, the efficiency of GTL fuel was slightly lower than conventional diesel and 50%-50% blend with about (5 % - 1.7%) and (2% - 4 %) compared with conventional diesel, respectively.

Figure 4 illustrates that the engine brake specific fuel consumption (BSFC) decreases with increase in load. In addition, it was observed that by using GTL fuel the BSFC decreases by approximately (4.8-17) % and (0.7- 6 %) compared with GTL and 50%-50% blend. The higher heating value of GTL fuel than conventional diesel improved the BSFC. Besides, as shown in the bellow figure 5. It was observed that GTL fuel had lower BSFC comparable to conventional diesel and 50%-50% blend. It had been found that while speed increases, BSFC decreases. GTL fuel has the lowest BSFC compared with conventional diesel and 50%-50% GTL by approximately average 31.28 % and 5.2%, respectively.

B. Engine emissions

Figure 5 shows the version in CO emissions for conventional diesel, GTL and 50%-50% blend at various loads constant speed 1700 rpm. On average, GTL fuel has the lowest CO emissions of about 43% lower than the other tested fuels. It is obvious that the GTL fuel in 50%-50% blended fuel has a significant effect to reduce CO emissions. This is probably due to higher GTL hydrogen to carbon ratio leading to improve the combustion process in addition to the very low aromatic content and higher cetane number in GTL fuel. The variation of CO emission with speed at constant load is displayed in Fig. 5. It shows that a slight decreasing of CO formation whereas the engine speed increases. In general, GTL fuel shows 42% less CO emissions than conventional diesel. The results also demonstrates that 50%-50% blended fuel has a lower CO emissions than conventional diesel by about 24%.

Figure 6 shows the relation between NO_x emissions with load variation at constant speed 1700 rpm. The results indicate a gradual increase in NO_x emission with load. GTL fuel has the lowest NO_x emissions compared with conventional diesel and 50%-50% blends by about 12.8% and 34.6%, respectively. This is considered to be a significant advantage of using GTL fuel. This NO_x reduction can be linked with the high cetane number, which reduces ignition delay duration. Figure 6 gives a relation of NO_x emission with the engine speed for conventional diesel, GTL and blends at a constant engine load with variation of speed. Overall, NO_x emissions decrease as the speed increases. Moreover, it can be observed that the GTL fuel ratio in the blends contributes to greater NO_x

emission reduction. The 50%-50% GTL blends and the pure GTL fuel give about 4.6 % and 10.5% reduction in NO_x emissions, respectively, comparing with diesel fuel.

Sulfur content is one of the fuel property that is responsible of sulfur oxides (SO_x) emissions which attracted the researchers and engine manufacturers to test a new fuels. In the combustion process, most of Sulphur content in diesel fuel is being oxidized to SO_2. These emissions together with exhaust gas from the exhaust system are then mostly vented into the atmosphere where they can be subject to other reactions contributing to the creation of photochemical smog and acid rain. However, some of SO_2 in a presence of oxygen can be unfavorably oxidized to SO_3. The high temperature of exhaust gas means that SO_3 stays in a vapor state and easily combines with after formed in the combustion process. Figure 7 depicts the variation of SO_2 exhaust emissions for the tested fuels at constant speed 1700 rpm with load variation. The results show a slight increase of SO_2 emissions as the load increases. GTL fuel has a very low SO_2 emissions comparing with conventional diesel and 50%-50% blends by approximately 50.1 % and 79.6 %, respectively.

Figure 7 compares SO_2 emissions of the test fueled by conventional diesel, GTL and 50%-50% blends at constant load variable speed operating conditions. On average, GTL fuel gives the lowest emissions, while 50%-50% blended fuel shows about 52.2 % reduction. Adding GTL to conventional diesel has a positive effect to enhance the reduction in SO_2 emissions. The reduction in SO_2 emissions can be explained by the fact that GTL has almost no Sulfur content. Moreover, some SO_2 formed during the combustion process combine with hydrocarbons or metals forming sulphates as it can be occurred while using GTL fuel. Metals originate from the products of the engine reciprocating and rubbing abrasion as well as from lubricating oil, fuel (catalyst residue) or erosion of the catalytic emission control system.

IV. Conclusions

In this work, GTL fuel has been used in direct injection diesel engine as a pure fuel and blended with conventional diesel fuel. In cylinder pressure was measured for a wide range of operating conditions to investigate the combustion characteristics of both fuels and their blends. Moreover, engine performance and emissions have been studied in order to evaluate the suitability of GTL fuel as an alternative fuel for engines. The results show that comparable maximum in cylinder pressure for both GTL and diesel fuels. However, the engine efficiency is slightly lower with GTL fuel than diesel fuel. BSFC shows improvements with GTL fuel in comparison with diesel fuel and blends. CO and NOx emissions have reduced significantly when using GTL and 50%-50% blends. SO2 emissions is the lowest reduction due to the fact that the Sulfur content in GTL fuel is close to 0%.

Acknowledgments

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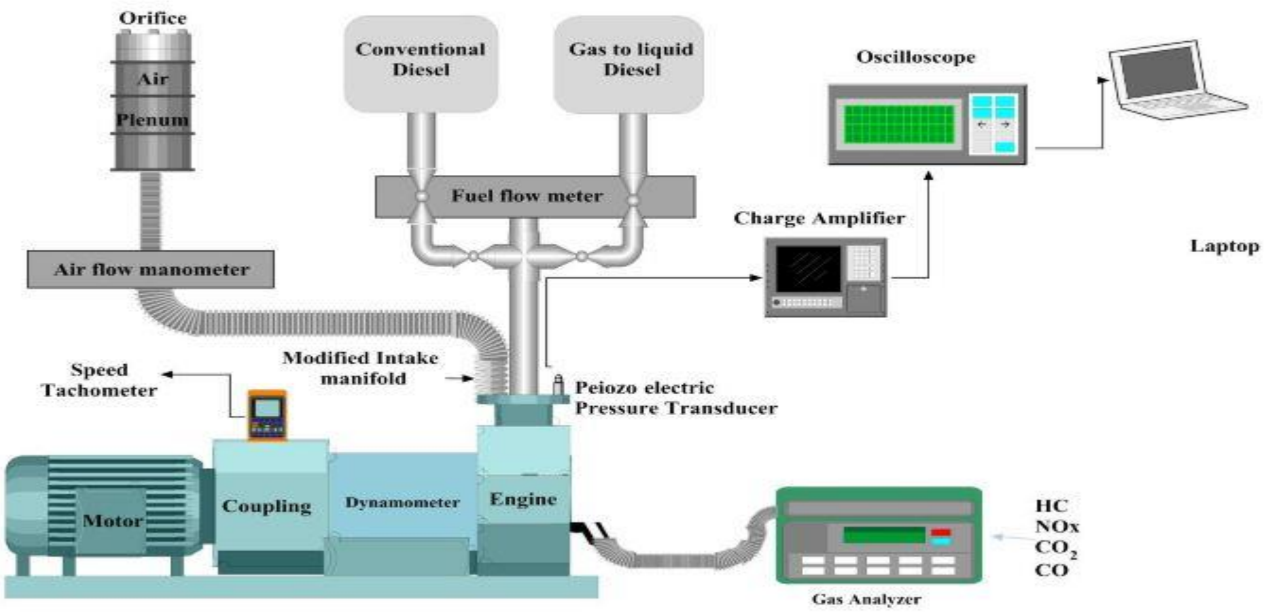

Figure 1. A schematic diagram of the diesel engine test rig and the experimental setup.

Table 1. Engine specifications.

Parameter	**specification**
No. Cylinders	single cylinder,4-stroke
Engine Type	Compression ignited
Type of Cooling	Water-Cooled Engine
Bore (m)	0.082 m
stroke (m)	0.068m
Max.Power (H.P.)	6.5 H.P.
Used Fuel	Diesel or GTL

Table. 2 Fuel properties [14].

Property	**Diesel**	**GTL**
Density at 15 C (kg/m^3)	866	760
Kinematic viscosity at 40 C (cSt)	1.6-7.0	1.5
Flash point (1C) (closed cup)	55	>55
Calorific value (MJ/kg)	44.3	47.3
Cetane No..(min)	55	70
Carbon content (% by weight)	86.98	94
Hydrogen content (% by weight)	12.99	1.6

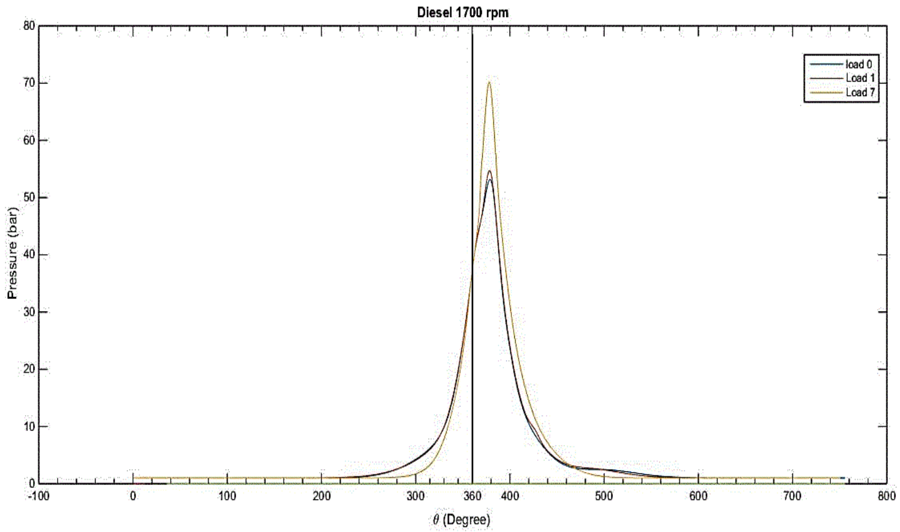

Figure 2. Typical pressure rise waveform inside the engine cyclinder at different loads with diesel fuel.

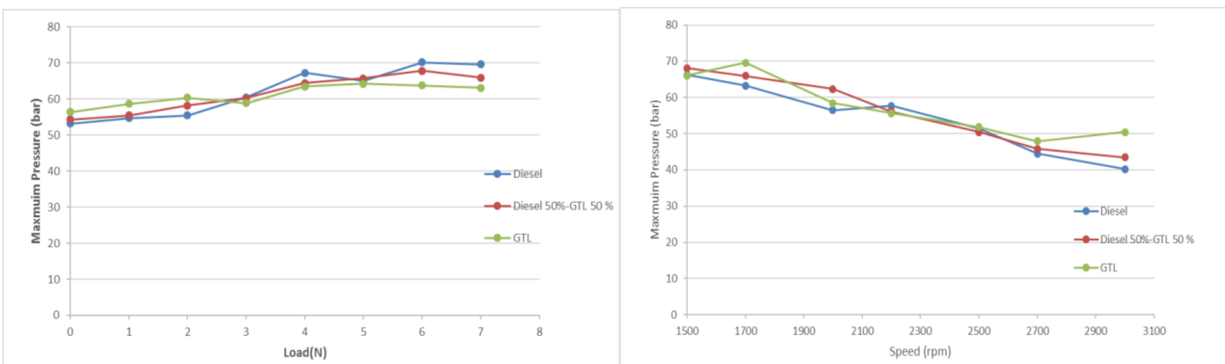

Figure 3: Maximum pressure measurements at different loads and speeds of GTL, diesel and blends

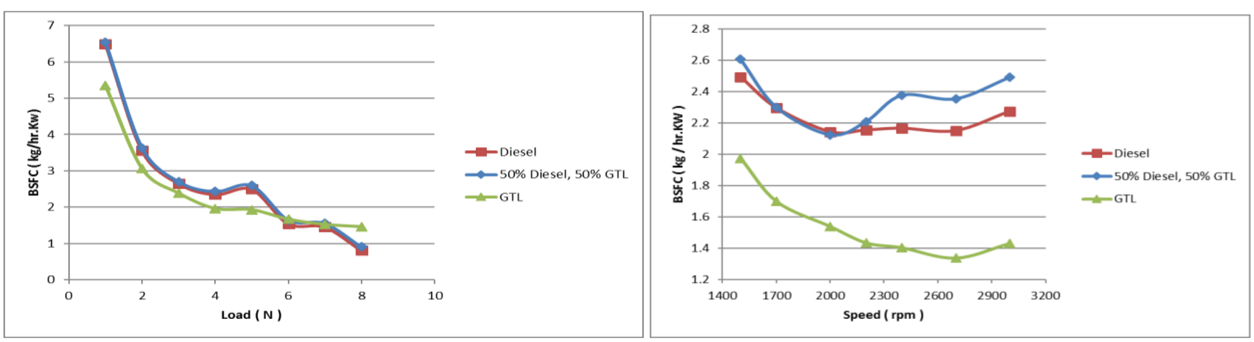

Figure 1. BSFC of diesel and GTL fuel blends with at different loads and speeds.

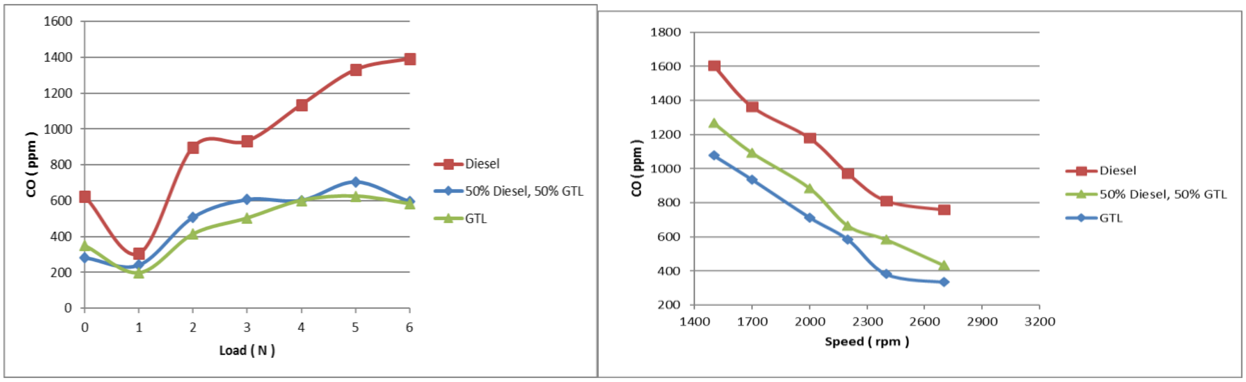

Figure 5.CO emissions of diesel and GTL fuel blends effect with different loads and speeds.

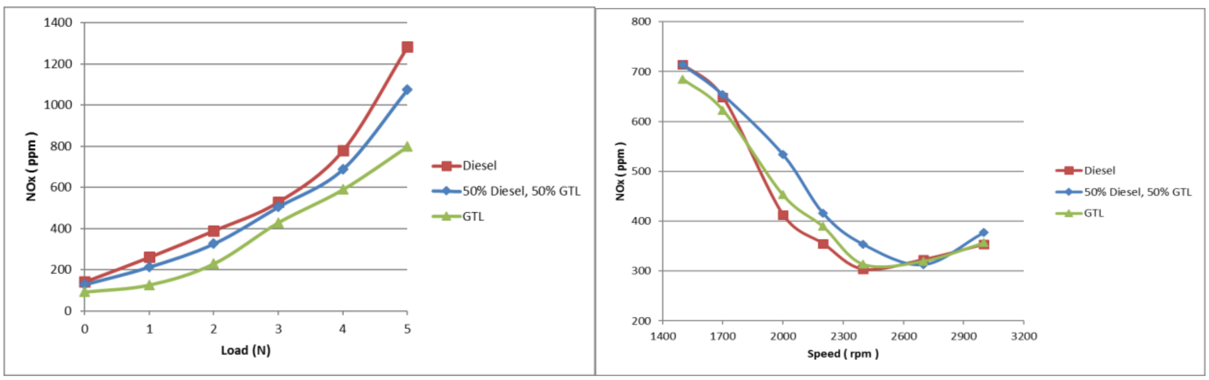

Figure 6. NO_x emissions of diesel and GTL fuel blends with different loads and speeds.

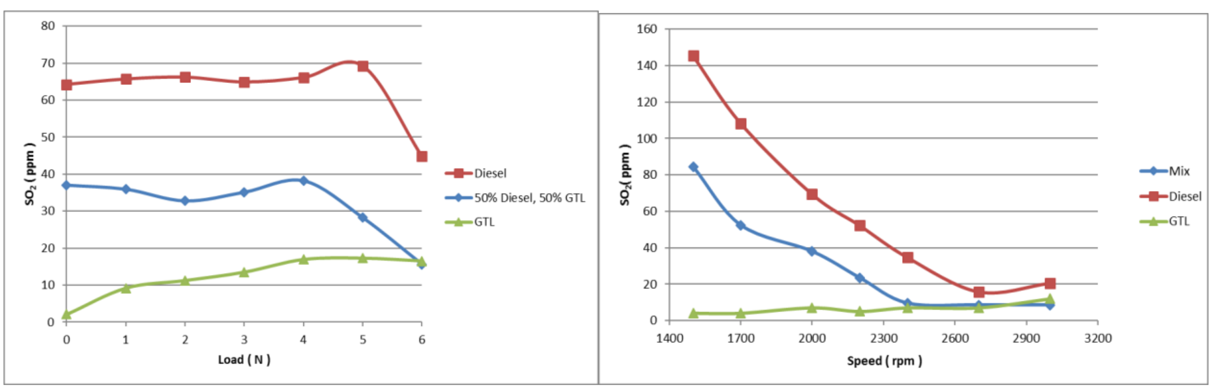

Figure 7. SO_2 emissions of diesel and GTL fuel blends with different loads and speeds.