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Investigation of the performance and emission of diesel engine fuelled by dual-fuel diesel and LP gas

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Abstract

Diesel engines are popular due to their fuel efficiency, performance, and cost-effectiveness. Advancements in diesel engines have made them compatible with alternative fuels like Compressed natural gas (CNG), Liquefied natural gas (LNG), and Liquefied petroleum gas (LPG). The LPG is a cleaner, more preferred, and widely used gaseous fuel, making it a preferred alternative to diesel. The current study is focused on investigating and comparing some performance parameters of diesel engines fueled with pure diesel fuel and dual-fuel diesel and LPG. A factorial experiment was conducted on a one-cylinder, four-stroke direct-injection, and water-cooled diesel engine fuelled with 1000 cc/min of LPG and run at a fixed speed (1500 rpm) with different loads (5, 10, and 15 Nm) and compression ratio (17). The results showed a reduction in brake-specific fuel consumption (BSFC), fuel cost, nitrogen oxide (NOx), and carbon dioxide (CO2) by 18, 20, 41, and 16% respectively.

Key words: Internal combustion engine, carbon dioxide, liquefied petroleum gas.

Introduction

Diesel engines are used in transportation, agriculture, and industry because of their dependability, durability, and excellent thermal efficiency. However, there are two fundamental obstacles to the utilization of diesel engines. One is concerned with the sustainability of fossil fuels, while the other deals with environmental worries about engine emissions. So far, diesel engines have implemented several technological innovations to reduce fuel consumption and pollutant emissions [2].

Liquefied petroleum gases are hydrocarbons produced by purifying crude oil, often from propane-butane or a combination. Propylene, butylene, and other hydrocarbons are frequently present but are not the primary component. It is one of several representations utilized in various domains, such as agriculture, industry, building engineering, economics, transportation, and household applications. This gas is derived from three primary sources: natural gas extraction, oil refining, and the stabilization of oil in crude oil reservoirs [13],[17].

Liquefied petroleum gas and diesel fuel can blend in any quantity. Diesel-LPG blends can function in diesel engines in a similar fashion to diesel fuel. While the mixed fuel has the potential to reduce diesel fuel consumption, the advantageous properties of LPG fuel, such as its low boiling point, tiny surface tension, and low viscosity, can enhance spray atomization and facilitate combustion [9].

Ergenç and Koca examined the utilization of LPG in diesel engines. An LPG injector was installed in the intake manifold. The measurements were conducted at LPG ratios of 10, 20, and 25%. The utilization of a 25% LPG ratio resulted in the most notable enhancements in engine power, torque, and specific fuel consumption. Within the context of exhaust emissions, the levels of NOx and HC emissions decreased across all LPG ratios [3].

These variables transfer the combustion process to the expansion stroke, reducing the amount of usable work generated by dual-fuel engines. During periods of low engine load, optimal combustion requires a powerful ignition source. Thus, to achieve optimal BSFC, it is necessary to maintain a large amount of pilot diesel fuel at low-load conditions [5],[8].

Under conditions of high engine loads, the combustion process mostly occurs due to the premixed ignition of the pilot fuel in the initial stage of combustion, followed by the diffusive ignition of the pilot fuel and simultaneous ignition of LPG in the subsequent stage of combustion. The combustion during the second phase is distinguished by its high speed. Thus, the duration of combustion is reduced while employing a higher concentration of LPG in comparison to operating with diesel fuel. Consequently, the dual fuel mode leads to an increased maximum pressure within the cylinder and a decreased BSFC [15].

When using dual fuel, adding LPG to the intake air decreases oxygen levels compared to burning diesel fuel. Consequently, a decrease in the formation of the NOx occurred [11].

The NOx concentrations in dual fuel mode were lower than in diesel mode. LPG fuel readily produces a homogeneous mixture with air, facilitating almost complete combustion and thus generating elevated temperatures within the engine throughout the combustion process. It enhances the probability of NOx production; higher temperatures lead to higher rates of dissociation. As the piston moves downward during the power stroke, the reactions' products will solidify, and the combustion chamber will be cooled by circulating water. This will lead to a significant reduction in the concentration of NOx [1],[7].

By adopting Diesel + LPG dual fuel operation, CO_2 emissions fell at all load percentages due to LPG's lower carbon-to-hydrogen ratio [16].

The combustion process during LPG use leads to a 35% decrease in CO_2 emissions. This decrease corresponds to the decrease in carbon content in the final mixture's overall composition [6],[12].

The rise in the external load resulted in a greater power need for doing the same work. This requires a higher fuel-burning rate and raising the torque will result in higher brake power, reducing brake-specific fuel consumption and reducing fuel cost [10].

The target of this research is to enhance diesel engine efficiency while lowering fuel consumption costs by working on dual-fuel (diesel + LPG) engines and gaining better control of exhaust emissions.

Material and methods

Engine Test

A one-cylinder direct injection water-cooled diesel engine with a variable compression ratio was utilized to conduct this study. The specification of the engine and test engine rig is shown in Table (1), and Figure (1) The emissions from the engine, including CO_2 and NO_x were monitored, and evaluated using a GASBOX TEXA multi-gas analyzer.

Mixed diesel fuel and LPG (D+LPG1000) were utilized in this research, and consumption was measured by an ECU unit, and the performance was compared with that of conventional diesel fuel.

Table (1) Test engine rig information.

Explanation	Technical details
Category	diesel engine
Make	Kirloskar (CI) engines
Rated power (Kw)	3.5 Kw
Bore (mm)	87.5 mm
Stroke (mm)	110 mm
Rated speed (rpm)	1500 rpm
Swept volume (cc)	661 cc
Compression ratio	17.5:1 modified to be variable
Method of starting	Manually or by alternator
Injection variation	0-25 deg BTDC.

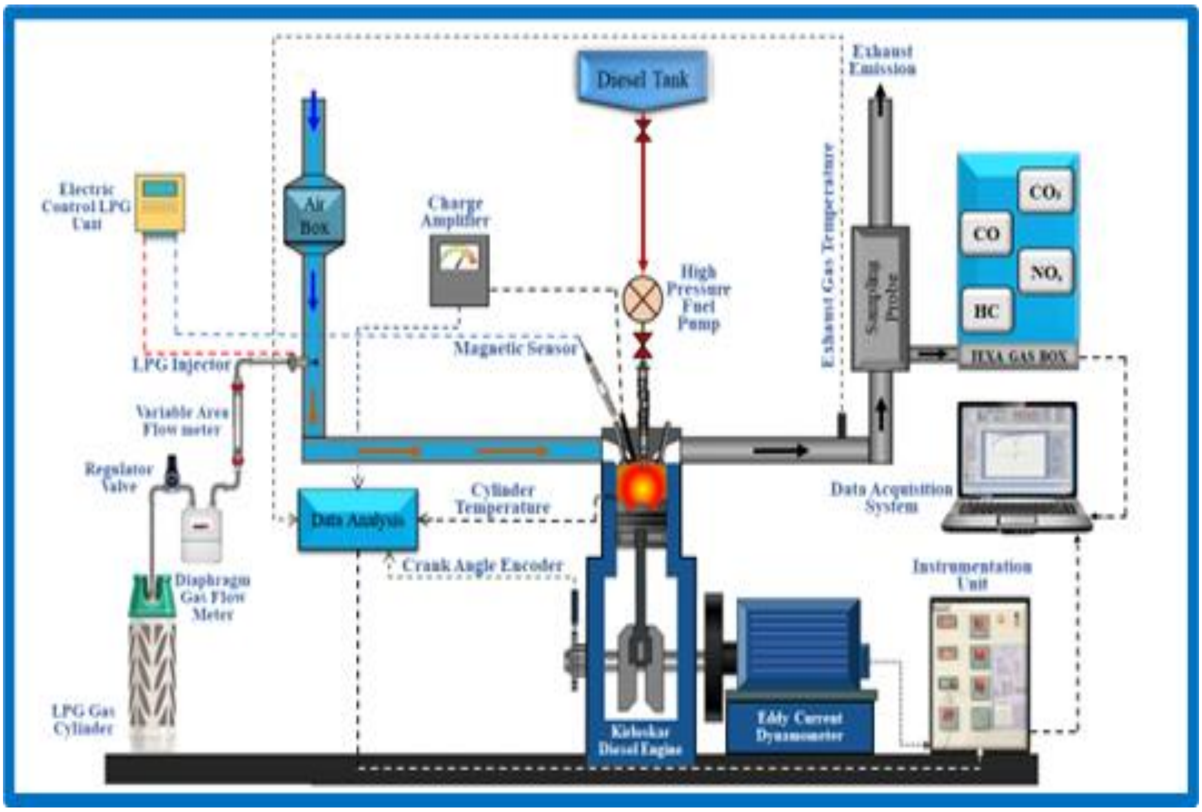

Figure (1) Schematic diagram of the test engine, LPG unit, and accessories [18].

Test Procedure

Initially, the engine ran on pure diesel fuel for a duration of 20 minutes under the unloading condition until it reached a stable state during the warm-up process. The engine speed was fixed at 1500 rpm then the selected load was applied, and the fuel consumption, NOx, and CO2 were measured for every load. The specific fuel consumption was measured by the equation of the [4].

BSFC =(m°f)/BP …. (1)

m°f =(sgr×ml×0.001)/t×3600 …. (2)

Where:

BSFC= Brake specific fuel consumption (Kg/kW.hr).

m°f = Fuel Consumption (kg/hr).

sgf = specific gravity of the fuel (kg/L). of Daura diesel fuel = (0.8333) Kg/L.

t = Duration required for the engine to use a certain quantity of fuel (sec).

The fuel cost was measured by equation (3) [14].

fuel cost = Fuel price x Hours …. (3).

Based on the Iraqi Ministry of Oil prices for the year 2024, the price of LPG is 200 ID per litre and the price of diesel fuel is 400 ID per litre.

The rates of engine emission were measured by the gas analyzer device (TAXA, Italy). The second step of the test included operating the engine by dual fuel diesel + LPG by injecting an LPG (1000 cc/min) in the air intake pipe. Then the same step was repeated when the engine worked on pure diesel. The results were collected and analyzed by factorial under a completely randomized design with the least significant (0.05) using GenStat 12.1 software. This study's target is to investigate the possibility of mixing and utilizing LPG fuel with diesel fuel to enhance engine performance and emission for diesel engines.

Results and Discussion

Brake-specific fuel consumption.

The effect of fuel types and torques on BSFC is illustrated in Figure (2). Interestingly, a clear reduction by 21, 9, and 19% at torques 5, 10, and 15 Nm respectively. This is because, in comparison to diesel fuel operation, the duration of combustion was shorter while utilizing a higher percentage of LPG. Consequently, the dual fuel mode leads to an elevated peak cylinder pressure and a reduced BSFC [15].

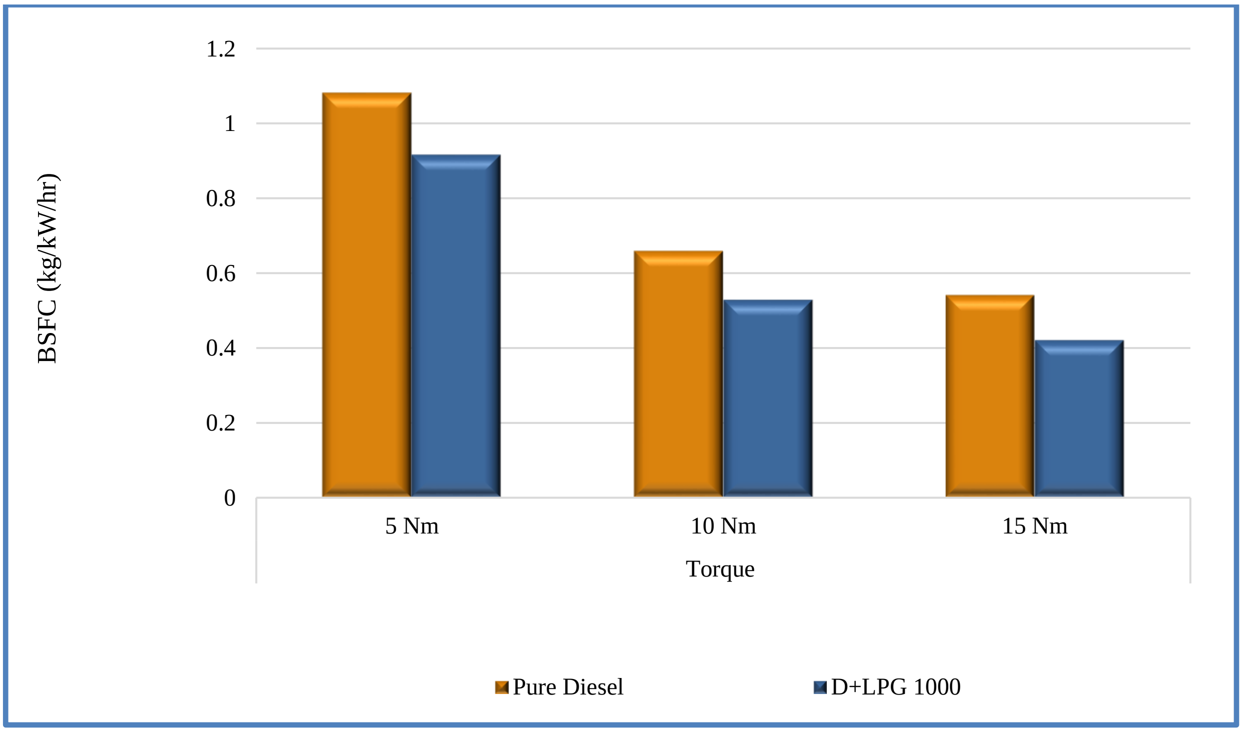

Figure (2) The effect of fuel type and load on BSFC.

Fuel cost.

Figure (3) shows the effect of fuel types and engine torques on Fuel cost. It is clear that there was a minimization in fuel cost when utilizing dual fuel by 19,19, and 22% at torques 5, 10, and 15 Nm respectively. The reason may be due to the lowest cost of LPG fuel compared the Pure diesel.

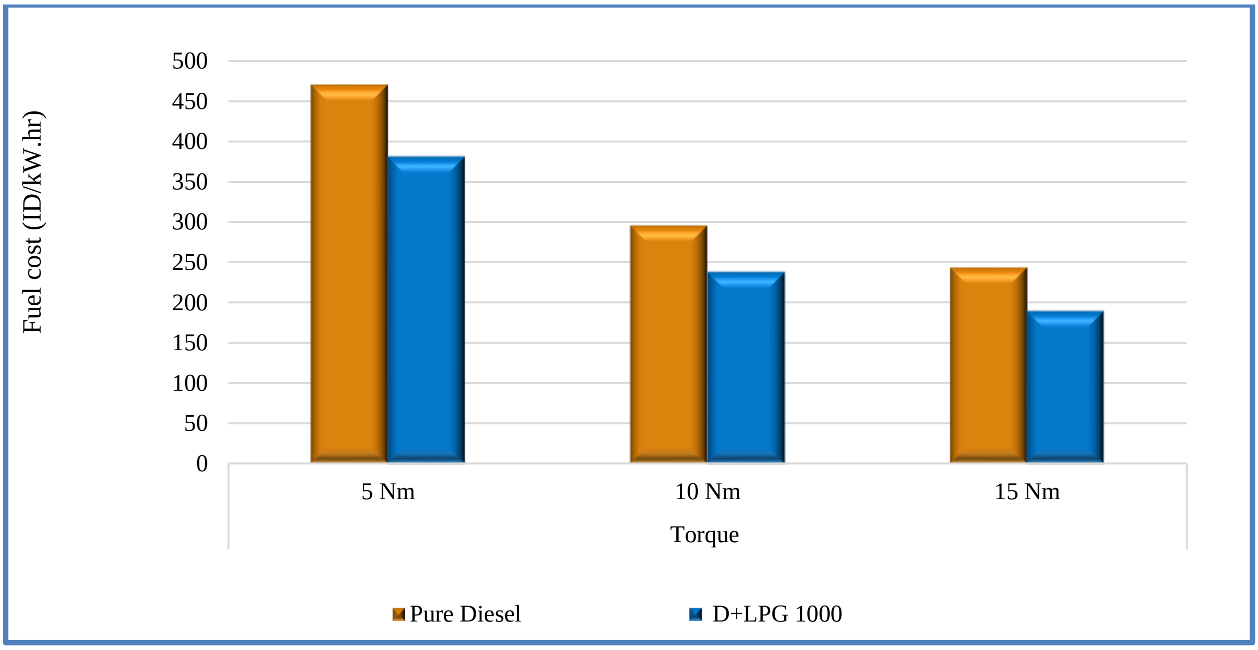

Figure (3) The effect of fuel type and load on fuel cost.

Nitrogen oxide

It is clear from Figure (4) that there was an obvious reduction in the percentage of NOx emissions when the engine runs dual fuel by 67,46, and 11% at torques 5, 10, and 15 Nm respectively. The reason may be using dual fuel, adding LPG to the intake air decreases oxygen levels compared to burning diesel fuel. Consequently, a decrease in NOx emission [11].

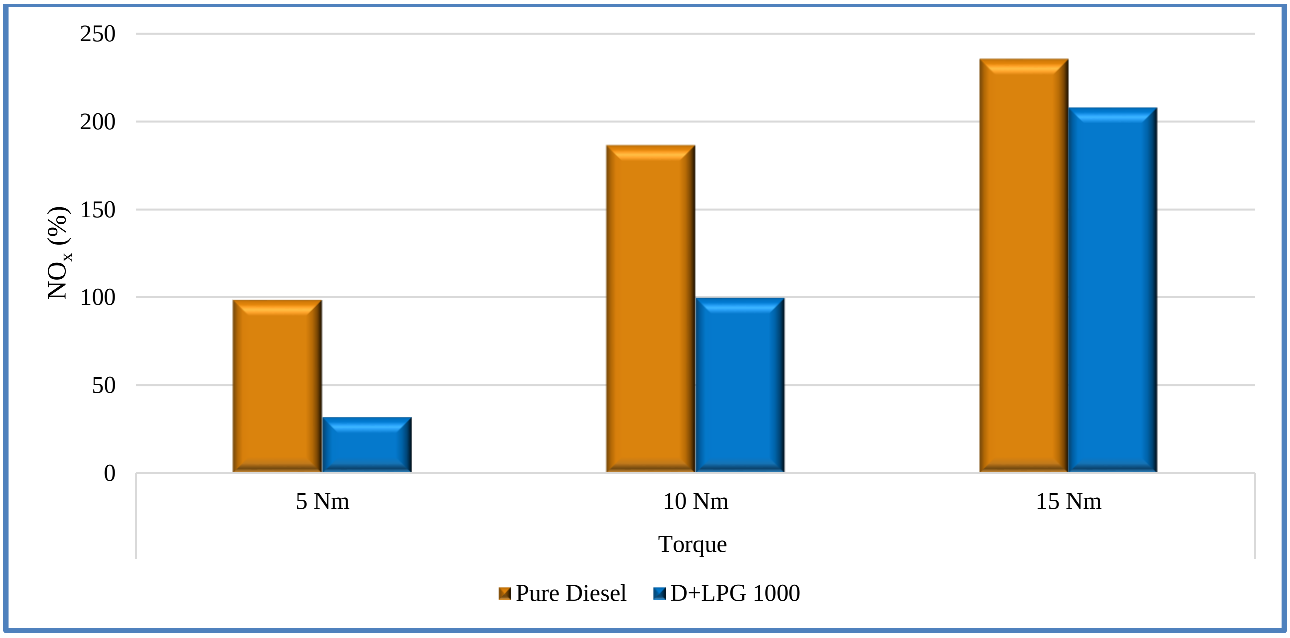

Figure (4) The effect of fuel type and load on oxide nitrogen.

Carbon dioxide

Figure (5) shows the variation in the concentration of CO2 when the engine runs on pure diesel, diesel + LPG fuel. Increasing engine torques was associated with Increased CO2 concentration. The rate of CO2 was reduced to the lowest concentration (1.853 %) for dual fuel diesel and LPG at torque 5 Nm. However, the highest rate of CO2 was 3.653 % when applying pure diesel with a torque of 15 Nm.

The reason may be that the combustion process during LPG leads to a decrease in CO2 emissions. This decrease corresponds to the decrease in carbon content in the final mixtures of the overall composition [12].

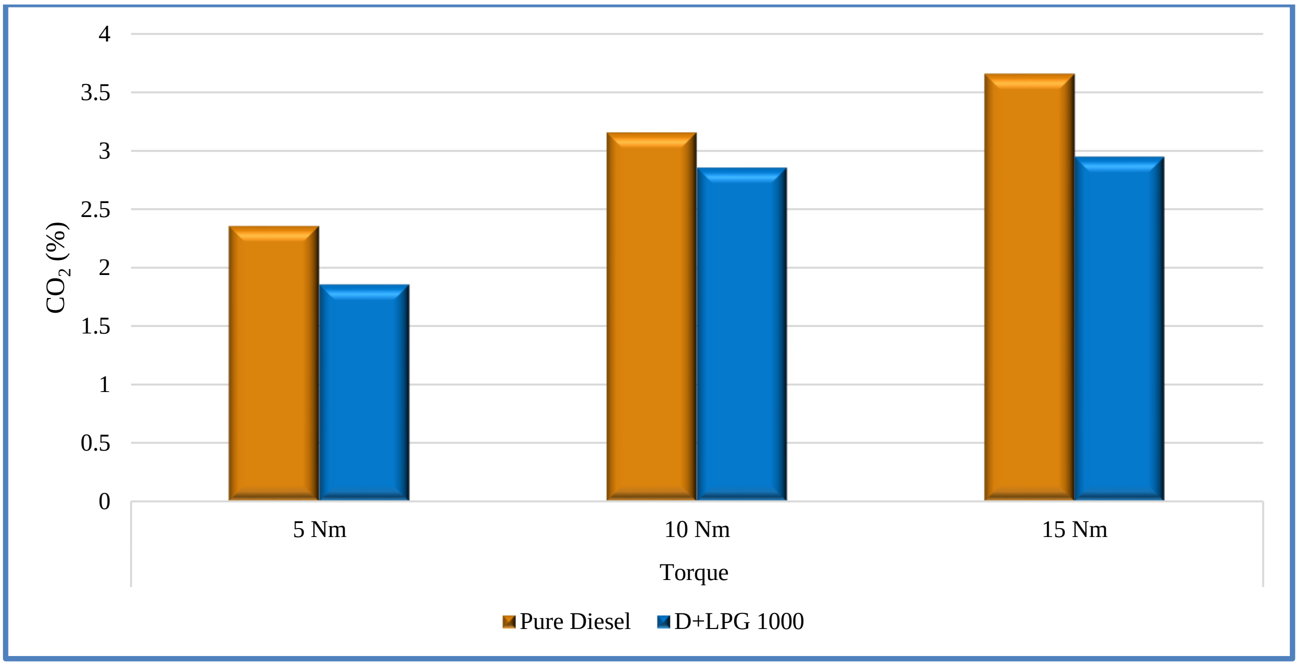

Figure (5) The effect of fuel type and load on carbon dioxide.

Conclusion

Based on the previously mentioned results, we found that, in comparison to pure diesel fuel, employing dual fuel (diesel + LPG 1000 cc/min) as an alternative fuel is appropriate for use with diesel engines and improves their performance and exhaust emission. In addition, reducing the BSFC and fuel cost for all engine torques. Moreover, improving engine emissions by reducing the concentration of NOx and CO2.

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References

1. Chaichan, M.T. (2011b) ‘Exhaust analysis and performance of a single cylinder diesel engine run on dual fuels mode’, Journal of Engineering, 17(04), pp. 873–885.
2. Chunilal, M. *et al.* (2016) ‘Effect of Variable Compression Ratio on The Performance of a Diesel Engine Fuelled With Diesel and Oxygenated Additives Blending’.
3. Ergenç, A.T. and Koca, D.Ö. (2014b) ‘PLC controlled single-cylinder diesel-LPG engine’, Fuel, 130, pp. 273–278. Available at: https://doi.org/https://doi.org/10.1016/j.fuel.2014.04.016.
4. Gupta, H.N. (2012) Fundamentals of internal combustion engines. PHI Learning Pvt. Ltd.
5. Heywood, J.B. (1988) Internal combustion engine fundamentals. McGraw-Hill.
6. Kadhim, N. S. (2013). Experimental investigation of three various sources of diesel fuel on the engine performance. Journal of Babylon University/Pure and Applied Sciences, 21(8), 2955.
7. Kamei, W., Sahoo, N. and Prasad, V.V.D.N. (2021) ‘Investigation of engine performance and combustion and use of oxidation catalysts in an LPG-diesel dual-fuel engine’, Journal of Energy Engineering, 147(6), p. 04021055
8. Klett, D.E. et al. (2017) ‘Internal combustion engines’, Energy Conversion, Second Edition, pp. 223–255. Available at: https://doi.org/10.1201/9781315374192.
9. Ma, Z. et al. (2007) ‘Effects of Fuel Injection Timing on Combustion and Emission Characteristics of a Diesel Engine Fueled with Diesel−Propane Blends’, Energy & Fuels, 21(3), pp. 1504–1510. Available at: https://doi.org/10.1021/ef060574a
10. Mahmood, A. et al. (2021) ‘The effect of compression ratio on the performance and emission characteristics of C.I. Engine fuelled with corn oil biodiesel blended with diesel fuel.’, IOP Conference Series: Earth and Environmental Science, 779, p. 012062. Available at: https://doi.org/10.1088/1755-1315/779/1/012062.

11. Mittal, M. et al. (2015) 'Exhaust emissions characteristics of a multi-cylinder 18.1-L diesel engine converted to fueled with natural gas and diesel pilot', Journal of the Energy Institute, 88(3), pp. 275–283. Available at: https://doi.org/https://doi.org/10.1016/j.joei.2014.09.003.
12. Nemoianu, L. et al. (2018) 'On LPG use at diesel engine: Pollutant emissions level and cycle variability aspects', in IOP Conference Series: Materials Science and Engineering. Institute of Physics Publishing. Available at: https://doi.org/10.1088/1757-899X/444/7/072002.
13. Paczuski, M. et al. (2016) 'Liquefied petroleum gas (LPG) as a fuel for internal combustion engines', Alternative fuels, technical and environmental conditions, 13.
14. Painter, K. (2011) 'The costs of owning and operating farm machinery in the Pacific Northwest 2011', A Pacific Northwest Publication, 346.
15. Qi, D.H., Chen, B. and Zhang, D. (2016) 'Combustion and exhaust emissions characteristics of a dual-fuel compression ignition engine operated with diesel fuel and liquefied petroleum gas', Journal of Energy Engineering, 142(4), p. 04016017.
16. Rosha, P., Bharj, R.S. and Gill, K.J.S. (2014) 'Performance and emission characteristics of Diesel+ LPG dual fuel engine with exhaust gas recirculation', International Journal of Science, Engineering and Technology Research (IJSETR), 3(10), pp. 2570–2574.
17. Ryskamp, R. (2017) 'Emissions and Performance of Liquefied Petroleum Gas as a Transportation Fuel: A Review', Center for Alternative Fuels, Engines and Emissions, West Virginia University [Preprint].
18. R., H. et al. (2022) "Optimization of variable compression ratio diesel engine fueled with Zinc oxide nanoparticles and biodiesel emulsion using response surface methodology," Fuel, 323. Available at: https://doi.org/10.1016/j.fuel.2022.124290.