Journal of Energy, Environmental & Chemical Engineering
2025, Vol. 11, No. 1, pp. 1-8
https://doi.org/10.11648/j.ijfmts.20251101.11

Research Article

Impact of Nerium-Water Emulsion with Diethyl Ether on Performance and Emission Reduction in a Direct Injection Diesel Engine

Mesay Dejene Altaye*

Department of Mechanical Systems and Vehicle Engineering, Adama Science and Technology University, Adama, Ethiopia

Abstract

This study investigated the impact of a Nerium-water emulsion, enhanced with diethyl ether (DEE) addition at 5%, 10%, and 15% concentrations, on the performance, combustion, and emissions of a direct injection (DI) diesel engine. Motivated by the need for sustainable fuels and reduced pollutant output, this research explored the potential of a Nerium-derived emulsion, leveraging DEE's oxygenating properties. Experiments were conducted on a single-cylinder, water-cooled diesel engine under steady-state conditions, analyzing in-cylinder pressure, heat release rate (HRR), nitrogen oxides (NOx), and smoke opacity. Brake thermal efficiency and specific energy consumption were also evaluated. The finding revealed that incorporating the Nerium-water emulsion DEE effectively decreased NOx and smoke opacity while largely maintaining brake thermal efficiency. Notably, higher DEE concentrations are generally correlated with greater emission reductions. The 15% DEE blend demonstrated the most promising results, achieving the lowest NOx and smoke opacity with minimal compromise to engine efficiency compared to the 5% and 10% blends. These results unequivocally highlight the synergistic advantages of employing a Nerium-water emulsion enriched with DEE as a fuel for a DI diesel engine. This approach offers a viable strategy for cleaner engine operation by utilizing a non-food biomass resource and significantly mitigating harmful emissions, thereby contributing to more sustainable transportation practices. The optimized blend with 15% DEE presents a particularly beneficial pathway for balancing performance and emission reduction in DI diesel engine applications.

Keywords

Diesel, Nerium Water Emulsion (NWE), Di-Ethyl Ether (DEE), NO_x Reduction

1. Introduction

Diesel engines are widely used in numerous industries due to their exceptional durability and thermal efficiency. However, growing concerns regarding the environmental repercussions of diesel combustion, especially the release of nitrogen oxides (NOx) and particulate matter (PM), have sparked significant interest in the study of alternative fuels and additives aimed at reducing harmful emissions and enhancing combustion performance [1]. Traditional diesel fuels are known to emit significant amounts of pollutants, including NOx, smoke opacity, and particulate matter, which pose se-

*Corresponding author: Mesay.dejene@astu.edu.et (Mesay Dejene Altaye)

Received: 17 March 2025; **Accepted:** 24 April 2025; **Published:** 6 June 2025

rious environmental and health risks [2]. As a result, there is an increasing need for sustainable fuel alternatives that can maintain engine performance while reducing these pollutants.

One promising approach to mitigating these issues is the use of water emulsions in diesel engines [3]. Neat Water Emulsion (NWE) fuel blends, where water is mixed with diesel, have been shown to significantly reduce the combustion temperature, thereby reducing the formation of NOx and particulate matter [4]. Water emulsions are known to enhance fuel atomization, improve combustion efficiency, and reduce smoke opacity, making them a potential candidate for achieving more eco-friendly diesel combustion [5]. The presence of water in the emulsion helps absorb heat [6], lowering the peak combustion temperature [7], which directly results in reduced NOx [8, 9] formation without compromising the power output [10]; or fuel consumption [11, 12].

To improve the performance of NWE blends, fuel additives like Diethyl Ether (DEE) are often added. DEE [13], a highly volatile and oxygenated compound, has been reported to improve ignition quality, reduce smoke opacity, and enhance engine efficiency [14]. The oxygen content in DEE promotes more complete combustion, which reduces the emissions of unburned hydrocarbons and particulate matter, while also potentially enhancing fuel efficiency [15].

In addition to these fuel blends, the incorporation of a plant-based fuel such as Nerium water emulsion has gained attention. Nerium oleander, known for its chemical properties, when emulsified with water and mixed with diesel, has shown promise in reducing harmful emissions and improving combustion characteristics [16]. The combination of Nerium oleander with water emulsion aids in reducing particulate matter and NOx emissions, potentially making it an environmentally friendly additive [17]. Studies indicate that Nerium-based emulsions possess certain catalytic properties that may contribute to enhanced fuel oxidation and lower emission rates [18].

This study investigates the effects of Nerium-water emulsion with varying concentrations of Diethyl Ether on engine performance, combustion characteristics, and emissions in a Direct Injection (DI) diesel engine. The results of this research can aid in developing cleaner diesel engine technology, minimizing environmental impact while preserving engine efficiency.

2. Literature Reviews

2.1. Characteristics and Benefits of Water-in-diesel Emulsions

Water emulsions are typically created by mixing water with diesel fuel in the presence of surfactants [19]. The resulting emulsion leads to better fuel atomization during injection and improved combustion due to the cooling effect of the water. According to research by [20], emulsified fuels reduce peak combustion temperatures, which directly impacts the reduction of NOx emissions without negatively affecting power output [21].

2.2. A Novel Approach, Nerium Water Emulsion

Recent studies have explored plant-derived emulsifiers like Nerium (Oleander) for their potential to enhance the stability and performance of fuel emulsions. However, it’s important to note that Nerium is toxic. [22], Its extract has demonstrated promising properties as a surfactant in biofuels. [10] Nerium-based emulsions create a stable interface for water dispersion and may reduce particulate matter (PM) in diesel engine exhaust.

2.3. Role of Diethyl Ether in Emission Reduction

Diethyl Ether (DEE) has long been recognized as a potential additive for diesel fuel to reduce harmful emissions. Its high oxygen content and volatility enhance the combustion process, leading to more complete fuel burning [23]. Diethyl ether serves as an oxygenate, enhancing the oxidation of fuel components and leading to lower HC (hydrocarbon) and CO (carbon monoxide) emissions. Research indicates [24], that incorporating diethyl ether into emulsified diesel fuel blends leads to significant reductions in nitrogen oxide (NOx) and particulate matter (PM) emissions. Additionally, this practice enhances overall engine performance metrics, such as brake thermal efficiency (BTE). Furthermore, water-in-diesel emulsions (WiDE) have also been shown to significantly decrease NOx emissions. For instance, a study demonstrated a maximum NOx reduction of 67.14% with a 30% water addition in emulsified fuel [10, 21]. The study demonstrated a 96.7% reduction in NO_2 and a 4.2% reduction in NOx emissions using emulsions with 15% and 18% water content.

2.4. Diethyl Ether as a Combustion Improver

Diethyl Ether can improve the ignition characteristics of diesel engines, reducing the formation of soot and particulate matter during combustion. A study by [25] highlighted that adding diethyl ether to a diesel-water emulsion blend resulted in improved combustion efficiency and a reduction in particulate emissions.

2.5. Performance Enhancement

The incorporation of emulsions (especially water and diethyl ether blends) has shown positive impacts on engine performance [26, 27] observed that the use of water-in-diesel emulsions in DI engines improved fuel efficiency due to enhanced combustion characteristics and reduced exhaust gas temperatures, which leads to lower thermal losses. Additionally, the cooling effect of water reduces the formation of NOx, a common byproduct of high-temperature combustion in diesel engines [28].

Direct Injection (DI) diesel engines are known for their high fuel efficiency and power output, but are also notorious for emitting high levels of NOx and particulate matter. By employing emulsified fuels, particularly those with additives like diethyl ether, significant improvements can be achieved. The use of emulsions also led to a 2.7% reduction in specific fuel consumption in a power plant setting [21].

3. Materials and Methods

This study examines the remarkable performance of a water-cooled, stationary, single-cylinder, vertical diesel engine with direct injection and a compression ratio of 17.5: 1. This impressive engine generated an extraordinary power output of 5.2 kW at a speed of 1500 rpm. The engine is fully equipped with a complete set of instruments for accurately measuring all operational parameters. The arrangement includes the necessary apparatus and systems to successfully conduct the intended experiment, such as a diesel engine, an eddy current dynamometer, an exhaust gas analyzer, and a smoke meter.

The experimental setup has been assembled using the following instruments, analyzers, and arrangements:

1)A research engine equipped with an alternator and an eddy current dynamometer.

2)A digital flowmeter and stopwatch setup are used to measure gasoline flow.

3)The piezoelectric pressure pickup allows for precise measurement of in-cylinder pressure.

4)The smoke meter is a tool that calculates the smoke density of engine exhaust.

To determine the composition of exhaust gases such as CO, HC, and NOx, an exhaust gas analyzer is employed.

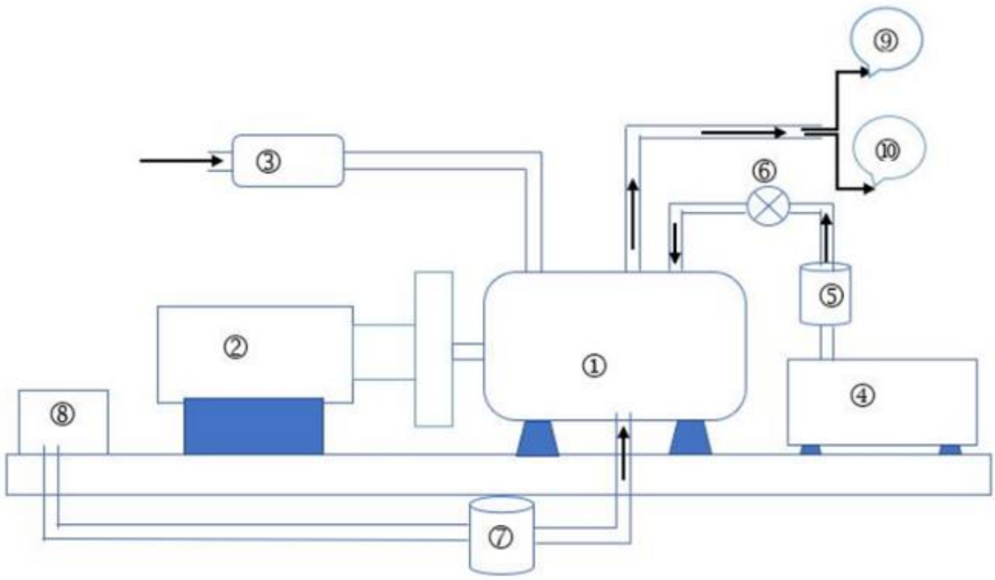

Figure 1. *Schematic view of the experimental setup.*

1. Diesel Engine 2. Eddy current Dynamometer 3. Airflow meter (orifice meter) 4. Fuel tank 5. Water pump 6. Fuel flow meter 7. Water container 8. Water container 9. Crypton Five Gas Analyzer 10. AVL smoke meter.

The engine operated under various environmental conditions until it reached a stable state. The experiments were repeated multiple times to obtain optimal readings for all variables. Both the test engine and the eddy current dynamometer were carefully positioned in concrete-embedded channels.

The Materials and Methods section should provide comprehensive details to enable other researchers to replicate the study and further expand upon the published results. If you have multiple methods, consider using subsections with appropriate headings to enhance clarity and organization.

4. Results & Discussion

4.1. Performance Characteristics

4.1.1. Brake Thermal Efficiency

Brake thermal efficiency is a crucial indicator of the combustion system's ability to utilize experimental fuel effectively and convert its energy into mechanical output. It represents the rate at which the chemical energy in the fuel is transformed into useful work. Moreover, it serves as a measure of the fuel's capacity to convert its chemical energy into productive output. By speeding up the combustion process at each stage, there is a greater potential to achieve higher brake thermal efficiency.

The graph presented in Figure 2 showcases the correlation between brake thermal efficiency and braking power. It reveals interesting findings about the efficiency of different types of fuels: diesel, NWE with 5% DEE, NWE with 10% DEE, and NWE with 15% DEE. At part load, the graph indicates that the brake thermal efficiency of these fuels stands at 27.61%, 24.9%, 25.5%, and 26.9%, respectively. It is worth noting that the brake thermal efficiency of NWE with 5% DEE is 9.78% lower than that of diesel fuel, which can be attributed to its lower calorific value and higher viscosity. However, the inclusion of DEE in the fuel mixture brings about positive changes. This improvement can be attributed to the high cetane number of DEE as well as its lower boiling temperature, which leads to enhanced atomization. Nevertheless, it is important to mention that using NWE with 15% DEE results in a 2.5% decrease in brake thermal efficiency compared to diesel fuel. With these insights, it becomes clear that various factors must be considered when assessing the thermal efficiency of different fuel options.

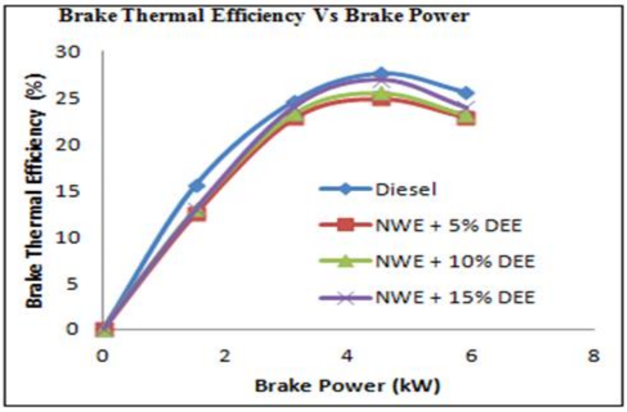

Figure 2. *Brake thermal efficiency Vs brake power.*

4.1.2. Brake-Specific Energy Consumption

The brake-specific energy consumption of the engine is determined by both the calorific value and the amount of fuel injected, and it is directly proportional to the mass flow rate of the fuel. In Figure 3, we can observe a graph that compares specific energy usage with the braking power. The data shows that the SEC values for diesel, NWE with 5% DEE, NWE with 10% DEE, and NWE with 15% DEE are 13594.17 kJ/kW-hr, 15199 kJ/kW-hr, 14000 kJ/kW-hr, and 13400 kJ/kW-hr, respectively.

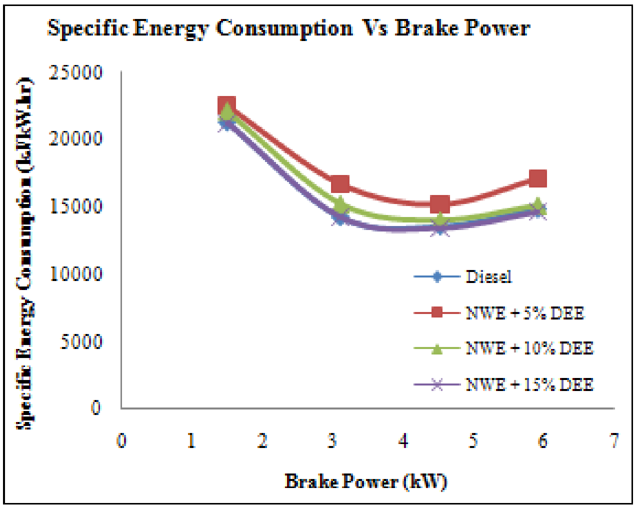

Figure 3. *Specific energy consumption Vs. brake power.*

NWE with 5% DEE consumes 11.8% more energy compared to diesel due to its higher specific gravity and lower calorific value. However, the specific energy consumption decreases as the amount of DEE added decreases, resulting in a decrease in the ignition delay period and minimizing the influence of water micro-explosion in the Nerium-water emulsion. Consequently, the NWE with 15% DEE has a 13.4% lower specific energy consumption than the NWE with 5% DEE.

4.2. Combustion Characteristics

4.2.1. Pressure

The relationship between pressure and crank angle is illustrated in Figure 4, which shows how various additives affect this connection. Upon analyzing the data, it becomes evident that the pressures of diesel, NWE with 5% DEE, NWE with 10% DEE, and NWE with 15% DEE were 72 bar, 66 bar, 69 bar, and 71 bar, respectively. The introduction of DEE, which has a higher cetane number, significantly reduces the ignition delay when used in combination with the Nerium water emulsion. Additionally, adding DEE results in a notable decrease in the viscosity of the emulsion. Compared to diesel, the reduced ignition delay leads to a significant drop in the maximum pressure of the Nerium water emulsion (NWE) with 5% DEE, 10% DEE, and 15% DEE, resulting in reductions of 8.33%, 4.16%, and 1.38%, respectively.

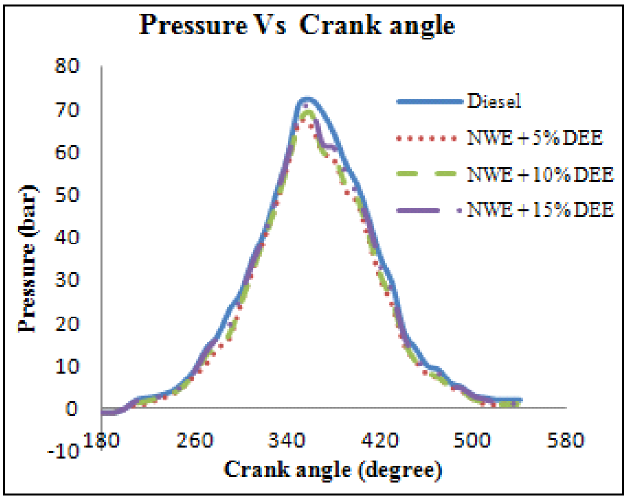

Figure 4. Pressure Vs. Crank angle.

4.2.2. Heat Release Rate

Figure 5 illustrates the relationship between the heat release rate and the crank angle. The graph demonstrates that the heat release rates for various fuel compositions, namely diesel, NWE with 5% DEE, NWE with 10% DEE, and NWE with 15% DEE, are all measured at 76.5 J/degree. CA, 70.5 J/deg. CA, 79.2 J/deg. CA, and 82.5 J/deg. CA, respectively. Notably, NWE, with 5% DEE, exhibited the highest heat release rate due to its extended ignition delay period and greater fuel consumption in the premixed combustion zone.

This can be attributed to the high cetane number and latent heat vaporization of DEE, which leads to a shorter ignition delay. Consequently, the heat release rate of NWE with 15% DEE decreased by 14.5% compared to NWE with 5% DEE. Moreover, the reduced heat release rate may be attributed to the increased amount of heat used during the combustion process.

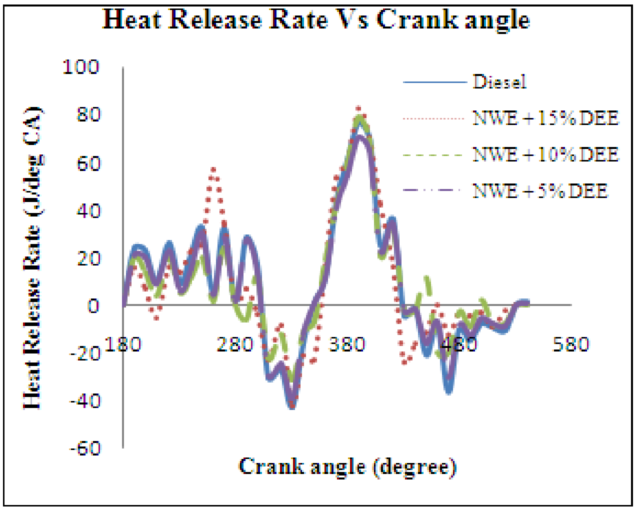

Figure 5. Heat release rate vs. crank angle.

4.3. Emission Characteristics

4.3.1. Hydrocarbon

Under high load conditions, hydrocarbon emissions in diesel engines are primarily caused by incomplete combustion and an excessively fuel-rich mixture. Wall quenching, lean mixing, and the combustion of lubricating oil also contribute to hydrocarbon emissions. However, when combustion is efficient, hydrocarbon emissions are significantly reduced. Extensive research has shown a direct correlation between the extent of burning and the level of hydrocarbon emissions. Moreover, the injection of fuel with larger droplet sizes and higher viscosity leads to suboptimal combustion. As a result, the fuel is inadequately burned, causing an increase in hydrocarbon emissions.

The graph in Figure 6 visually represents the relationship between hydrocarbons and brake power. It clearly shows that the hydrocarbon levels for diesel, NWE with 5% DEE, NWE with 10% DEE, and NWE with 15% DEE are 52 ppm, 54 ppm, 53 ppm, and 51 ppm, respectively. It is worth noting that DEE, which contains 21.6% oxygen, plays a crucial role in reducing the ignition delay. Consequently, this results from complete combustion and a significant reduction of hydrocarbon by 1.92% in NWE with 15% DEE compared to diesel.

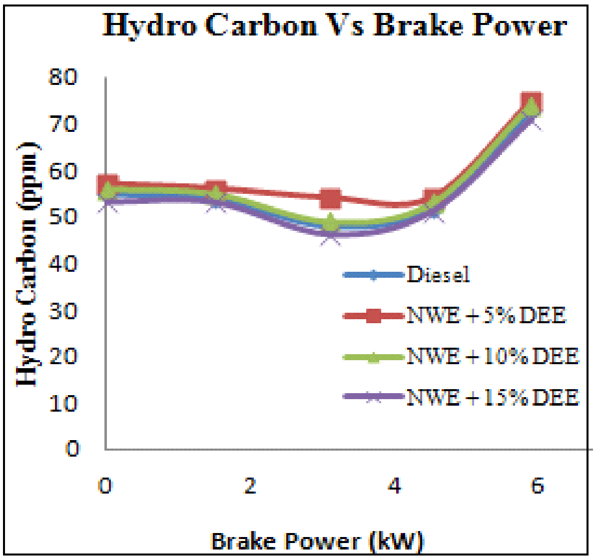

Figure 6. Hydrocarbon Vs brake power.

4.3.2. Carbon Monoxide

Carbon monoxide (CO) is a highly toxic gas that is produced when hydrocarbon fuels are burned, especially when there is an excess of fuel relative to the available air or when combustion is incomplete. The presence of CO in exhaust emissions indicates that some of the chemical energy from the fuel has been wasted, as the engine has not used it efficiently. The ratio of oxygen in the fuel-air mixture significantly affects the amount of CO produced.

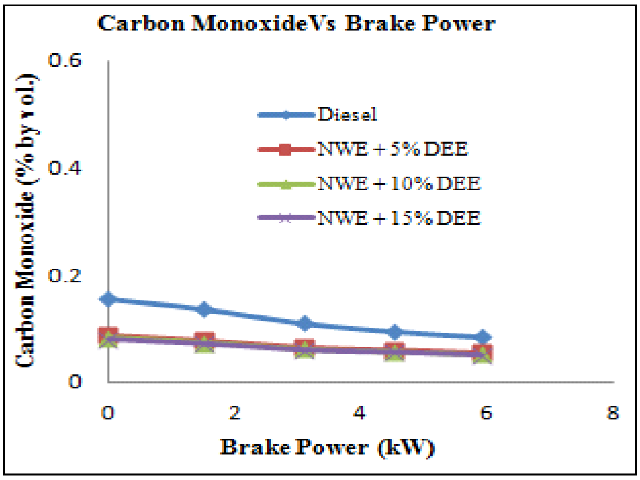

Figure 7. Carbon monoxide Vs brake power.

The graph in Figure 7 illustrates the relationship between carbon monoxide and braking power. This data reveals that the carbon monoxide content of diesel, NWE with 5% DEE, NWE with 10% DEE, and NWE with 15% DEE is 0.095%, 0.06%, 0.057%, and 0.055%, respectively. By incorporating DEE, an oxygenated chemical, into a Nerium water emulsion, carbon monoxide levels decrease. However, it is noteworthy that at a concentration of 15% DEE, the problem of vapor lock arises due to its high volatility.

4.3.3. Nitrogen Oxides

When exposed to high temperatures, oxygen atoms can break apart, triggering a chain reaction that is essential for combining nitrogen and oxygen.

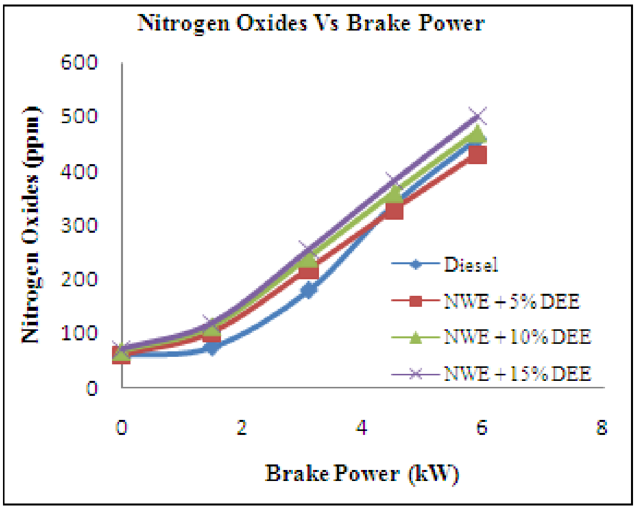

Figure 8. Nitrogen oxides Vs brake power.

This combination process ultimately leads to the formation of NOx. Consequently, factors such as the peak cycle temperature, the concentrations of oxygen and nitrogen atoms, and the duration of their interaction play significant roles in determining the generation of NOx.

Figure 8 showcases a visually appealing depiction of the correlation between brake power and nitrogen oxides. It clearly illustrates the impact of different fuel compositions, specifically diesel, NWE with 5% DEE, NWE with 10% DEE, and NWE with 15% DEE. The corresponding nitrogen oxide levels for these fuels were measured to be 340 ppm, 328.5 ppm, 360 ppm, and 405 ppm, respectively. Interestingly, the introduction of DEE led to a significant rise in nitrogen oxide emissions, indicating a higher rate of complete combustion. More notably, when the nitrogen oxides of NWE with 15% DEE were compared to those of diesel, a staggering 19.1% increase was observed.

4.3.4. Smoke

Smoke is a combination of solid soot particles and exhaust emissions. The levels of smoke increase as braking power intensifies. Emulsified fuel tends to emit slightly more smoke due to its higher viscosity, larger fuel droplets, and inadequate air and fuel mixing.

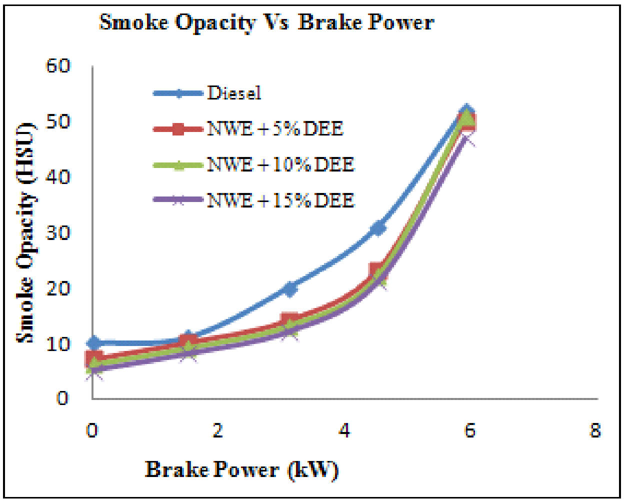

Figure 9. Smoke Vs brake power.

In Figure 9, we can observe the correlation between smoke opacity and brake power. The graph highlights that the smoke opacity levels for diesel, NWE with 5% DEE, NWE with 10% DEE, and NWE with 15% DEE were 31 HSU, 23.2 HSU, 22.1 HSU, and 21.1 HSU, respectively. Notably, the introduction of 21.6% oxygen by mass in DEE resulted in reduced smoke emissions for the Nerium water emulsion with DEE. In comparison to diesel, the smoke opacity for NWE with 15% DEE exhibited a notable increase of 19.1%.

5. Conclusions

This study successfully demonstrated the viability of a

Nerium-water emulsion (NEW) blended with 15% diethyl ether (DEE) as a direct substitute for conventional diesel fuel in a compression ignition engine, achieving comparable performance, combustion characteristics, and emission levels without engine modifications. This success underscores the significant potential of leveraging non-food biomass resources, such as Nerium, in conjunction with oxygenated additives like DEE, to create sustainable alternative fuels. The enhanced combustion attributed to DEE's high cetane number and latent heat of vaporization highlights the crucial role of fuel formulation in optimizing the utilization of such emulsions. While this research provides a promising foundation, several opportunities warrant future investigation. Future studies should focus on long-term engine performance and durability assessments, as well as exploring the optimization of DEE concentrations to further reduce emissions and improve fuel efficiency. Additionally, investigating the economic viability and scalability of NWE-DEE emulsion production will be crucial for its widespread adoption in the diesel engine sector.

Abbreviations

DI	Direct Injection
DEE	Di-ethyl Ether
HRR	Heat Release Rate
NEW	Nerium Water Emulsion
PM	Particulate Matter
BTE	Brake Thermal Efficiency
Wide	Water-in-diesel Emulsions
Kw	Killo Watt
CO	Carbon Monoxide
HC	Hydrocarbon
CA	Crank Angle
No_x	Nitrogen Oxides

Acknowledgments

The author expresses sincere appreciation to Adama Science and Technology University, the Department of Mechanical Systems and Vehicle Engineering, Automotive Section, located in Adama, Ethiopia.

Author Contributions

Mesay Dejene Altaye is the sole author. The author read and approved the final manuscript.

Funding

This study was not supported by any grants from funding bodies in the public, private, or not-for-profit sectors.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Maricq M Matti, "Chemical characterization of particulate emissions from diesel engines: A review", J Aerosol Sci 2007; 38(11): 1079–1118. https://doi.org/10.1016/j.jaerosci.2007.08.001

[2] A. M. Ithnin *et al.*, "Emulsifier-free Water-in-Diesel emulsion fuel: Its stability behaviour, engine performance and exhaust emission," *Fuel*, vol. 215, pp. 454–462, Mar. 2018, https://doi.org/10.1016/j.fuel.2017.11.061

[3] J. Sadhik Basha and R. B. Anand, "Effects of nanoparticle additive in the water-diesel emulsion fuel on the performance, emission and combustion characteristics of a diesel engine," *International Journal of Vehicle Design*, vol. 59, no. 2–3, pp. 164–181, 2012, https://doi.org/10.1504/IJVD.2012.048692

[4] B. K. Debnath, U. K. Saha, and N. Sahoo, "A comprehensive review on the application of emulsions as an alternative fuel for diesel engines," Feb. 01, 2015, *Pergamon*. https://doi.org/10.1016/j.rser.2014.10.023

[5] I. S. Anufriev, "Review of water/steam addition in liquid-fuel combustion systems for NOx reduction: Waste-to-energy trends," Mar. 01, 2021, *Pergamon*. https://doi.org/10.1016/j.rser.2020.110665

[6] S. Vellaiyan, "Recent advancements in water emulsion fuel to explore efficient and cleaner production from various biodiesels: A retrospective review," Nov. 01, 2023, *Pergamon*. https://doi.org/10.1016/j.rser.2023.113704

[7] K. Skalska, J. S. Miller, and S. Ledakowicz, "Trends in NOx abatement: A review," Sep. 2010. https://doi.org/10.1016/j.scitotenv.2010.06.001

[8] M. Song, Q. Huang, F. Niu, and S. Li, "Recirculating structures and combustion characteristics in a reverse-jet swirl pulverized coal burner," *Fuel*, vol. 270, p. 117456, Jun. 2020, https://doi.org/10.1016/j.fuel.2020.117456

[9] M. El-Adawy, M. A. Ismael, I. B. Dalha, A. R. A. Aziz, and W. El Maghlany, "Unveiling the status of emulsified water-in-diesel and nanoparticles on diesel engine attributes," *Case Studies in Thermal Engineering*, vol. 44, p. 102824, Apr. 2023, https://doi.org/10.1016/j.csite.2023.102824

[10] V. K. Gaur *et al.*, "Production of biosurfactants from agro-industrial waste and waste cooking oil in a circular bioeconomy: An overview," Jan. 01, 2022, *Elsevier*. https://doi.org/10.1016/j.biortech.2021.126059

[11] S. Woo and K. Lee, "Stability characteristics according to cumulative time after manufacturing of water emulsion fuel prepared by porous membrane method for low-pollutant engines," *Fuel*, vol. 331, Jan. 2023, https://doi.org/10.1016/j.fuel.2022.125711

[12] L. Aguado-Deblas *et al.*, "Diethyl ether as an oxygenated additive for fossil diesel/vegetable oil blends: Evaluation of performance and emission quality of triple blends on a diesel engine," *Energies (Basel)*, vol. 13, no. 7, p. 1542, Mar. 2020, https://doi.org/10.3390/en13071542

[13] B. Q. Doan, X. P. Nguyen, V. V. Pham, T. M. H. Dong, M. T. Pham, and T. S. Le, "Performance and emission characteristics of diesel engine using ether additives: A review," Feb. 01, 2022, *Diponegoro university Indonesia - Center of Biomass and Renewable Energy (CBIORE)*. https://doi.org/10.14710/ijred.2022.42522

[14] A. Wiangkham, N. Klinkaew, P. Aengchuan, P. Liplap, A. Ariyarit, and E. Sukjit, "Experimental and optimization study on the effects of diethyl ether addition to waste plastic oil on diesel engine characteristics," *RSC Adv*, vol. 13, no. 36, pp. 25464–25482, Aug. 2023, https://doi.org/10.1039/d3ra04489k

[15] M. Moorthi, A. Murugesan, and A. Alagumalai, "Effect of nanoparticles on DI-CI engine characteristics fueled with biodiesel–diesel blends—A critical review," Sep. 01, 2022, *Springer Science and Business Media B. V.* https://doi.org/10.1007/s10973-022-11234-6

[16] N. Khalid *et al.*, "Nerium oleander could be used for sustainable management of traffic-borne elemental-enriched roadside soils," *Environmental Science and Pollution Research*, vol. 30, no. 14, pp. 40551–40562, Mar. 2023, https://doi.org/10.1007/s11356-023-25160-z

[17] A. Gupta *et al.*, "A comparative study of the impact on combustion and emission characteristics of nanoparticle-based fuel additives in the internal combustion engine," Jan. 01, 2024, *John Wiley & Sons, Ltd*. https://doi.org/10.1002/ese3.1614

[18] H. Alahmer *et al.*, "Optimal Water Addition in Emulsion Diesel Fuel Using Machine Learning and Sea-Horse Optimizer to Minimize Exhaust Pollutants from Diesel Engine," *Atmosphere*, vol. 14, no. 3, Mar. 2023, https://doi.org/10.3390/atmos14030449

[19] S. Vellaiyan and K. S. Amirthagadeswaran, "The role of water-in-diesel emulsion and its additives on diesel engine performance and emission levels: A retrospective review," Sep. 01, 2016, *Elsevier*. https://doi.org/10.1016/j.aej.2016.07.021

[20] F. Pereira and C. Silva, "Combustion of Emulsions in Internal Combustion Engines and Reduction of Pollutant Emissions in Isolated Electricity Systems," *Energies*, vol. 15, no. 21, p. 8053, Oct. 2022, https://doi.org/10.3390/en15218053

[21] C. Kiran and D. N. Prasad, "A review on: Nerium oleander Linn. (Kaner)," 2014.

[22] B. Venkatesh, J. C. Babu, S. K. Mathivanan, P. Jayagopal, S. Prasanna, and M. S. Uddin, "Influences of Aqueous Nanofluid Emulsion on Diesel Engine Performance, Combustion, and Emission: IoT (Emission Monitoring System)," 2022, *Hindawi Limited*. https://doi.org/10.1155/2022/8470743

[23] A. K. Agarwal, Prashumn, H. Valera, and N. Nath Mustafi, "Di-ethyl ether-diesel blends fuelled off-road tractor engine: Part-II: Unregulated and particulate emission characteristics," *Fuel*, vol. 308, p. 121973, Jan. 2022, https://doi.org/10.1016/j.fuel.2021.121973

[24] A. I. EL-Seesy, M. S. Waly, Z. He, H. M. El-Batsh, A. Nasser, and R. M. El-Zoheiry, "Enhancement of the combustion and stability aspects of diesel-methanol-hydrous methanol blends utilizing n-octanol, diethyl ether, and nanoparticle additives," *Journal of Cleaner Production*, vol. 371, p. 133673, Oct. 2022, https://doi.org/10.1016/j.jclepro.2022.133673

[25] P. Dinesha, S. Kumar, and M. A. Rosen, "Combined effects of water emulsion and diethyl ether additive on combustion performance and emissions of a compression ignition engine using biodiesel blends," *Energy*, vol. 179, pp. 928–937, Jul. 2019, https://doi.org/10.1016/j.energy.2019.05.071

[26] M. R. Seifi *et al.*, "Statistical evaluation of the effect of water percentage in water-diesel emulsion on the engine performance and exhaust emission parameters," *Energy*, vol. 180, pp. 797–806, 2019, https://doi.org/10.1016/j.energy.2019.04.093

[27] M. A. Saadeldin, M. M. Elgohary, M. M. Abdelnaby, and M. R. Shouman, "Effects of Direct Water Injection on the Nitrogen Oxide Emission Characteristics of Marine Diesel Engines," *Journal of Marine Science and Technology (Taiwan)*, vol. 31, no. 2, pp. 145–156, 2023, https://doi.org/10.51400/2709-6998.2692

[28] B. C. Benea, "The influence of water injected on the reduction of NOx emissions in Diesel engine," *IOP Conference Series: Materials Science and Engineering*, vol. 1256, no. 1, p. 012039, 2022, https://doi.org/10.1088/1757-899x/1256/1/012039