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PERFORMANCE ANALYSIS OF CI ENGINE BY USING DIESEL AND DISTILLED WATER

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Abstract

The ubiquitous challenge of achieving a harmonious balance between the growing energy demands and the imperatives of environmental sustainability remains formidable. The exploration of alternative fuels and fuel-blending techniques for CI engines emerges as a pivotal strategy to ameliorate emissions without compromising engine performance. This research elucidates the experimental investigation into the performance and emission characteristics of a CI engine when operated on diesel and a formulated blend of diesel and distilled water.

A meticulous examination of the engine's thermal efficiency, brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), and emissions (such as NOx, CO, CO2, and particulate matter) across a spectrum of load conditions was undertaken. A series of tests were conducted by employing neat diesel and diesel-water emulsions in varied volume fractions, ensuring a comprehensive analysis under identical operational conditions. Emulsified fuels were prepared using a surfactant to stabilize the water in diesel to prevent phase separation and ensure a homogeneous mixture.

Intriguingly, the results manifest that the incorporation of distilled water into diesel resulted in discernible alterations in the performance and emission traits of the CI engine. Notably, a reduction in NOx and particulate matter emissions was observed with the use of water-diesel emulsions, primarily attributed to the water's latent heat, which curtailed peak combustion temperatures. However, a meticulous evaluation of the impact on BSFC, BTE, and other performance metrics was imperative to ascertain the viability of diesel-water blends.

Moreover, the water inclusion subtly mitigated the calorific value of the blend, demanding an analytical scrutiny of the engine's durability and long-term performance. The encompassing findings of this research pave the way for a nuanced understanding of the potentials and challenges imbued in utilizing diesel-water emulsions as a viable fuel alternative for CI engines, prompting further research into optimization strategies and comprehensive engine testing to propel this innovative approach to sustainable fuel use into pragmatic applications.

Keywords: CI Engine, Diesel-Water Emulsion, Emission Characteristics, Engine Performance, Alternative Fuels, Sustainable Energy, Environmental Impact, Thermal Efficiency.

I. INTRODUCTION

The integration of water into diesel intends to leverage the inherent properties of water to moderate combustion temperatures and thereby, potentially curtail NOx emissions – a phenomenon substantiated by the Jelalian water effect. The induction of water either by direct injection or by forming stable emulsions with diesel tends to mitigate peak combustion temperatures, which, in theory, should consequently reduce the formation of thermal NOx during combustion.

Concurrently, the mitigation of combustion temperatures and alterations in the combustion dynamics, typically associated with water incorporation, evoke a necessity to thoroughly investigate and understand its pervasive impacts on engine performance, efficiency, and other emissions, to ascertain the practicability and efficacy of diesel-water emulsions as an alternative fuel.

Objectives of the Study:

This research pivots on empirically investigating the multi-faceted impacts of utilizing diesel-water emulsions in a CI engine, examining:

- The performance attributes including brake thermal efficiency, specific fuel consumption, and thermal efficiency.
- The emission characteristics focussing on NOx, CO, CO2, and PM across varied load conditions.
- The stability and compatibility of diesel-water emulsions, as well as their impact on the durability and long-term performance of the engine.

LITERARURE SURVY

- **Selim and Elfeky:** Investigated the control of NOx emissions in a diesel engine by using water emulsion with indirect injection. Found that blending water in diesel reduced emissions when using 8% water.
- **Abu-Zaid:** Studied the performance of a diesel engine using various water emulsion percentages and a surfactant. Reported improvements in brake thermal efficiency and reduced exhaust gas temperatures at higher water emulsion ratios.
- **ARMAS et al.:** Conducted experiments on a turbocharged intercooler diesel engine using a 10% water emulsion. Noted improvements in brake power and reductions in NOx, soot, HC, and PM emissions.
- **Kannan and Anand:** Investigated emissions and performance of diesel engines using biodiesel-ethanol-diesel and water emulsion blends. Observed improvements in brake-specific fuel consumption (BSFC) and reduced emissions.
- **Ithnin et al.:** Reviewed the utilization of diesel and water emulsion in diesel engines, concluding that it increased thermal efficiency and reduced NOx and PM emissions but increased HC and CO emissions.
- **Ogunkoyaet al. :** Explored the performance and emissions of diesel engines using a bio-based macromolecule and a 70:30 water emulsion. Reported longer ignition delays, improved mechanical efficiency, and reduced NOx emissions.

PROBLEM STATEMENT

The research aims to investigate the utilization of water-emulsified diesel fuel in diesel engines to assess its impact on engine performance and emissions. The study seeks to determine whether the use of emulsified fuels can yield improvements in performance and emission profiles without requiring engine modifications. However, a potential concern is the possibility of engine component corrosion due to the presence of water in the emulsion. The study will also explore the phenomenon of rapid water evaporation through micro-explosions, as proposed by Kweonha Park et al. [7], which could mitigate the risk of cylinder surface corrosion. This research addresses the need for a comprehensive understanding of the benefits and challenges associated with water-emulsified diesel fuel, contributing to the existing literature on emulsified fuels in diesel engines.

LIMITATIONS

- ✓ **Limited Publication Dates:** Many of the references provided earlier do not include publication years. This can make it difficult to assess the relevance and currency of the research. Up-to-date studies are crucial in evaluating the current state of knowledge in the field.
- ✓ **Heterogeneity of Research Methods:** Different studies may employ varying experimental setups, engine types, emulsion compositions, and testing conditions. This heterogeneity can make it challenging to directly compare and generalize results across studies.
- ✓ **Incomplete Data:** Some studies may not provide comprehensive data on all relevant engine performance parameters and emissions. This can limit the ability to draw definitive conclusions or perform quantitative meta-analyses.
- ✓ **Lack of Standardization:** The lack of standardized testing protocols and reporting standards in the field of emulsified fuels can lead to inconsistencies in data collection and reporting.

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- ✓ **Short-Term Experiments:** Some studies may focus on short-term experiments, providing insights into immediate effects but not considering the long-term durability and reliability of water-emulsified diesel fuels in real-world applications.
- ✓ **Limited Focus on Corrosion:** While corrosion is mentioned as a potential drawback, detailed investigations into the corrosion effects and mitigation strategies may be limited in the existing literature.
- ✓ **Geographical and Engine Specificity:** Research findings may be specific to certain geographical regions or engine types, making it challenging to extrapolate results to other contexts.
- ✓ **Surfactant Variability:** Studies involving emulsified fuels often use different types and concentrations of surfactants. The choice of surfactant can significantly impact emulsion stability and combustion characteristics, but these details may not always be thoroughly explored in the literature.
- ✓ **Small Sample Sizes:** Some studies may have limited sample sizes or a narrow scope, potentially limiting the statistical significance of their findings.
- ✓ **Publication Bias:** Research that yields statistically significant or positive results may be more likely to be published, while studies with null or negative findings may not be as readily available in the literature, potentially leading to publication bias.

II. METHODOLOGY

CI Engine:

A CI (Compression Ignition) engine, also known as a diesel engine, is an internal combustion engine that operates by compressing air within a combustion chamber to a temperature and pressure that is sufficient to ignite the fuel injected into the chamber. Unlike spark ignition engines (such as gasoline engines) that use a spark plug to initiate combustion, CI engines rely on the heat generated by compression to ignite the fuel.

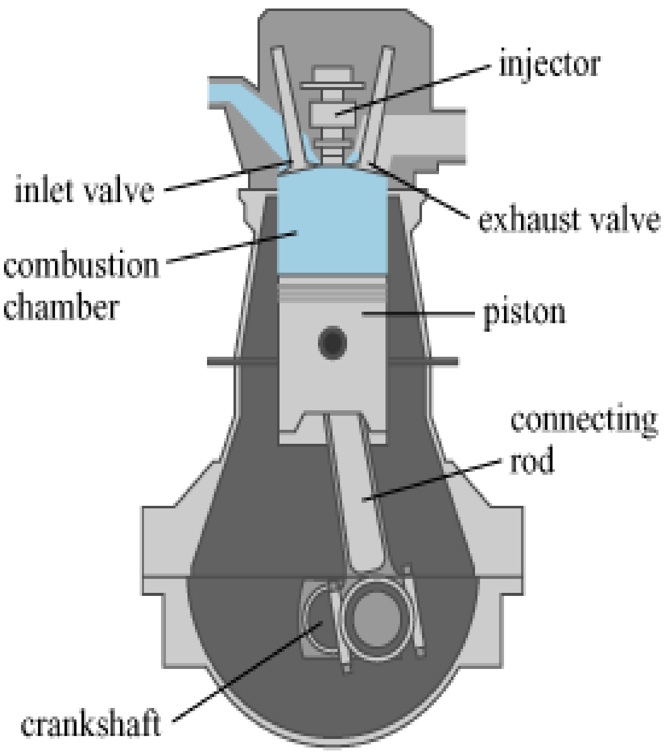

Figure 1: CI (Compression Ignition) engine

Here are some key characteristics and features of CI engines:

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- **Compression Ignition:** The name "compression ignition" comes from the fact that the air-fuel mixture is compressed to a high pressure and temperature, causing spontaneous ignition. Diesel fuel is injected into the hot, compressed air, and it ignites without the need for a spark.
- **Diesel Fuel:** CI engines typically use diesel fuel, which has a higher energy density than gasoline and is more suitable for compression ignition. Diesel fuel consists of hydrocarbons and is less volatile than gasoline.
- **Higher Efficiency:** CI engines are known for their higher thermal efficiency compared to spark ignition engines. This efficiency is due to the higher compression ratios and the absence of throttle valves, which reduces pumping losses.
- **Torque:** CI engines are well-suited for applications requiring high torque, such as heavy-duty trucks, buses, construction equipment, ships, and industrial machinery. They excel in tasks that demand significant pulling or hauling power.
- **Fuel Efficiency:** Diesel engines are known for their fuel efficiency, making them a preferred choice for long-haul transportation and commercial applications where fuel economy is crucial.
- **Turbocharging:** Many CI engines are equipped with turbochargers to increase air intake and improve power output. Turbocharging helps boost engine performance without increasing engine displacement.
- **Durability:** Diesel engines are known for their robustness and durability. They are designed to withstand heavy workloads and are often used in applications where engines are subjected to continuous operation.
- **Emissions:** While diesel engines are efficient, they can produce emissions of nitrogen oxides (NOx) and particulate matter (PM). Emissions control technologies, such as selective catalytic reduction (SCR) and diesel particulate filters (DPF), are used to meet stringent emission regulations.
- **Variety of Applications:** CI engines are used in a wide range of applications, including transportation (trucks, buses, locomotives), agriculture (tractors), construction (excavators, bulldozers), marine (ships, boats), power generation (diesel generators), and industrial machinery.
- **Alternative Fuels:** Research is ongoing to develop alternative fuels for CI engines, including biodiesel, synthetic fuels, and natural gas, to reduce greenhouse gas emissions and reliance on fossil fuels.

CI engines have been a crucial part of various industries for many decades and continue to evolve with advancements in technology, emissions control, and alternative fuels to meet environmental and efficiency challenges.

CI Engine by using Diesel and Distilled Water:

Using a combination of diesel fuel and distilled water in a compression ignition (CI) engine is a concept known as water-in-diesel emulsion or water-diesel emulsion. This approach involves mixing small amounts of water with diesel fuel to create an emulsion that is then used as a fuel in the engine. The idea behind this technology is to improve engine performance and reduce emissions. Here's how it works and its potential benefits and challenges:

How Water-Diesel Emulsion Works:

- ✓ **Emulsion Preparation:** Water and diesel fuel are mixed together to create a stable emulsion. This process often involves the use of additives or surfactants to ensure the water and diesel remain mixed together.
- ✓ **Fuel Injection:** The emulsified fuel is injected into the engine's combustion chamber, similar to regular diesel fuel.
- ✓ **Combustion:** During the compression stroke of the engine, the air-fuel mixture is compressed to a high temperature and pressure. In the case of water-diesel emulsion, the water droplets in the mixture turn into steam due to the high temperature. This steam can help improve the combustion process by increasing the overall temperature inside the cylinder.

Potential Benefits:

- **Emissions Reduction:** Water-diesel emulsions can lead to reduced emissions of nitrogen oxides (NOx) and particulate matter (PM). The steam generated by the water can lower combustion temperatures, which helps reduce NOx formation. Additionally, it can lead to more complete combustion, reducing PM emissions.

- **Improved Efficiency:** The steam generated by the water can increase the overall efficiency of the engine by providing additional expansion work during the power stroke.

- **Cooling Effect:** The water in the emulsion can have a cooling effect on the engine, potentially reducing the risk of overheating.

- **Cleaner Combustion:** Water-diesel emulsions can lead to cleaner combustion and reduced soot formation, contributing to cleaner engine internals.

Challenges:

- **Corrosion:** One of the main challenges with water-diesel emulsions is the potential for increased corrosion of engine components due to the presence of water. Corrosion can affect fuel injectors, valves, and other parts.

- **Fuel Stability:** Emulsified fuels may require specific storage and handling conditions to maintain their stability. Water can separate from the diesel fuel over time if not properly managed.

- **Engine Modifications:** Some engines may require modifications to accommodate emulsified fuels, such as changes to fuel injection systems or materials to resist corrosion.

- **Energy Content:** Water has no energy content, so using water in the emulsion can decrease the energy density of the fuel, potentially leading to reduced power output.

- **Maintenance:** Maintenance requirements may increase when using water-diesel emulsions due to potential corrosion issues.

Water Emulsified Diesel and Methodology:

Water-emulsified diesel, also known as water-diesel emulsion, is a fuel mixture consisting of diesel fuel and water. This emulsion can be used as an alternative fuel in diesel engines. The water content in the emulsion helps improve combustion efficiency and reduce emissions. Below is a general methodology for preparing and using water-emulsified diesel:

Methodology for Preparing Water-Emulsified Diesel:

- **Gather Ingredients:** You will need diesel fuel and distilled water as the main ingredients. Additionally, you may require a surfactant or emulsifying agent to stabilize the emulsion.

- **Determine Water-to-Diesel Ratio:** The water content in the emulsion can vary, typically ranging from 2% to 20% of the total volume, depending on the desired effects. Lower water content is used for emissions reduction, while higher water content can provide cooling effects and further emissions reduction.

- **Mixing:** To create the emulsion, mix the water and diesel fuel thoroughly. Depending on the specific formulation, you may need to use a mechanical emulsification system or an emulsifying agent to ensure a stable mixture. This process helps break down the water into tiny droplets suspended in the diesel fuel.

- **Surfactant Addition (Optional):** If needed, add a surfactant or emulsifying agent to stabilize the emulsion. Surfactants help maintain the stability of the water droplets in the diesel fuel.

- **Testing and Quality Control:** Perform tests to ensure the emulsion is stable and well-mixed. This may include visual inspection, particle size analysis, and testing for water separation.

Methodology for Using Water-Emulsified Diesel in an Engine:

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- **Engine Compatibility:** Ensure that your diesel engine is compatible with water-emulsified diesel. Some engines may require modifications to accommodate this fuel type.
- **Fuel Injection System Adjustments:** Depending on the water content and emulsion stability, you may need to adjust the fuel injection system to optimize combustion.
- **Start with Low Water Content:** If you are using water-emulsified diesel for the first time, start with a lower water content (e.g., 2-5%) to avoid potential engine issues.
- **Performance Testing:** Run performance tests with the emulsified fuel, monitoring parameters such as engine power output, fuel efficiency, and emissions.
- **Emissions Analysis:** Measure emissions, including nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and hydrocarbons (HC), to assess the environmental impact of the emulsified fuel.
- **Data Collection:** Collect data on engine performance and emissions to compare with baseline results obtained using pure diesel fuel.
- **Gradual Increase in Water Content:** If the initial tests are successful, you can gradually increase the water content in the emulsion to achieve specific performance and emissions targets.
- **Corrosion Monitoring:** Keep an eye on potential corrosion issues in the engine components due to the presence of water. Corrosion can be mitigated through additives or engine modifications.
- **Maintenance and Monitoring:** Regularly monitor the engine's performance and conduct maintenance as necessary to address any issues related to the use of water-emulsified diesel.
- **Optimization:** Continuously optimize the emulsion formulation, engine settings, and operating conditions to achieve the desired balance between performance, emissions reduction, and engine longevity.

Water-emulsified diesel can offer benefits such as reduced emissions and improved combustion efficiency. However, it is essential to follow a systematic methodology to ensure safe and effective implementation in diesel engines, considering both fuel preparation and engine operation aspects.

III. RESULTS & DISCUSSION

The objective of this experimental investigation was to assess the impact of varying water content in diesel fuel, specifically diesel, diesel with 10% water content (D10), and diesel with 20% water content (D20), on the performance and emissions of a light-duty single-cylinder diesel engine. The outcomes of this experimentation are visually depicted in Figure 2.

ENGINE PERFORMANCES:

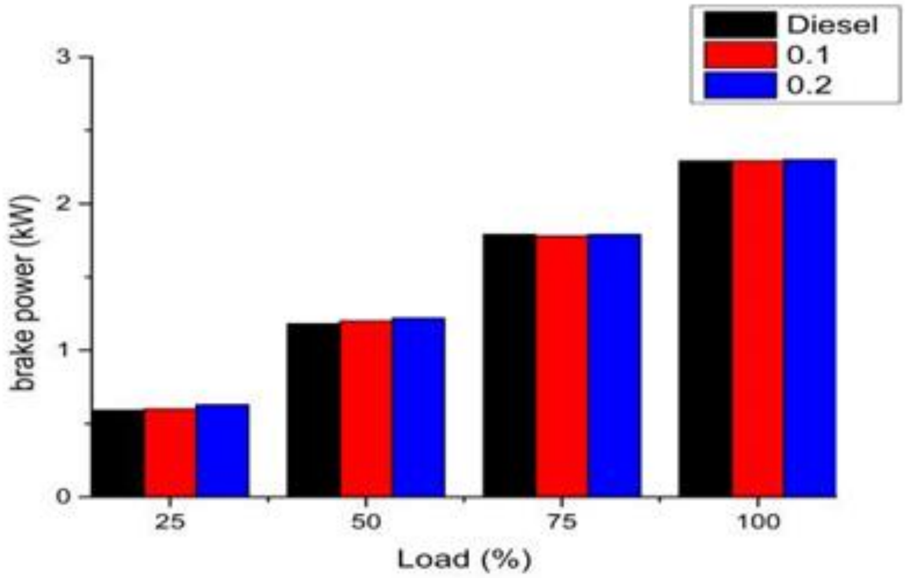

Figure 2: Load Vs Brake Power

Load vs. Brake Specific Fuel Consumption:

Figure-2 illustrates that the brake specific fuel consumption (BSFC) experiences a consistent reduction under all operating conditions as the water content in the emulsion increases. This decrease in BSFC is a direct consequence of the greater proportion of water within the emulsion, which displaces an equivalent volume of diesel. Consequently, there is less diesel fuel present per unit volume of the emulsion, resulting in a lower BSFC. The minimum BSFC value is achieved when the water content reaches 30%. The utilization of emulsified fuel primarily leads to an enhancement in brake specific fuel consumption and thermal efficiency, primarily attributable to the reduction in heat losses.

Under all load conditions, Figure-3 demonstrates that the brake specific fuel consumption (BSFC) diminishes with an increase in the percentage of water within the emulsion. This decline in BSFC can be attributed to the fact that a greater proportion of water replaces an equivalent volume of diesel in the emulsion. Consequently, the emulsion contains less diesel fuel per unit volume, leading to a reduction in BSFC. The lowest BSFC value is attained when the water content reaches 30%. The utilization of emulsified fuel is likely to enhance brake specific fuel consumption and thermal efficiency primarily by minimizing heat losses.

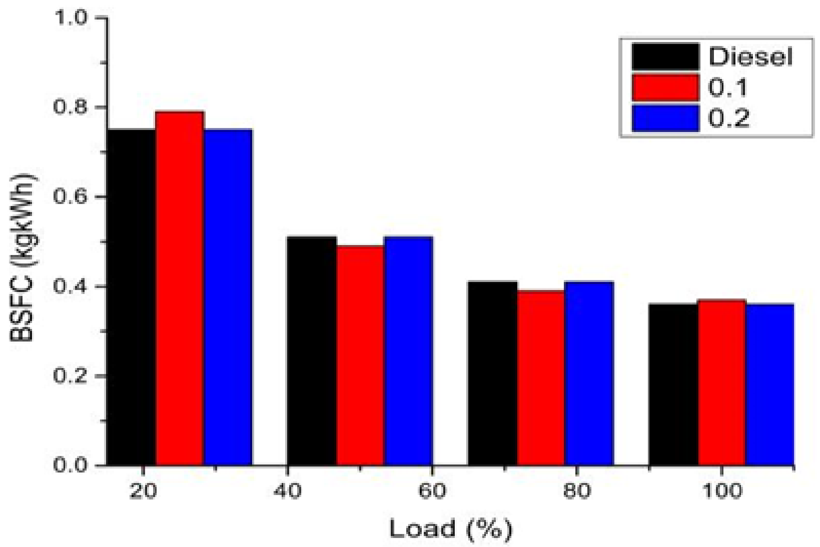

Figure 3: Load Vs Brake Specific Fuel Consumption

Load vs. Brake Thermal Efficiency:

Figures 4 depict the influence of water content in diesel-water emulsion on brake thermal efficiency and indicated efficiency. As the proportion of water in the emulsion increases, there is a concurrent increase in brake thermal efficiency. This phenomenon arises from the presence of water in the emulsion, which augments the expansion work while reducing the compression work, ultimately resulting in an amplified net work output during the engine cycle. The expansion of water vapor contributes an additional force atop the piston, elevating the torque generated throughout the cycle. In the diesel-water emulsion, an equivalent volume of diesel is substituted by water per unit volume. Consequently, the heightened net work output and reduced fuel consumption combine to yield higher brake thermal efficiency and indicated efficiency.

This outcome aligns with the findings of Abu-Zaid, who conducted experiments illustrating that the peak brake thermal efficiency is achieved when a 30% water content in the emulsion is employed in a single-cylinder diesel engine. Additionally, Jamil Ghojel et al. reported that the brake thermal efficiency of diesel oil emulsions tends to be somewhat higher across the test range in heavy-duty industrial diesel engines. In the case of a light-duty IDI diesel engine, the utilization of emulsified fuel enhances engine efficiency under specific operating conditions.

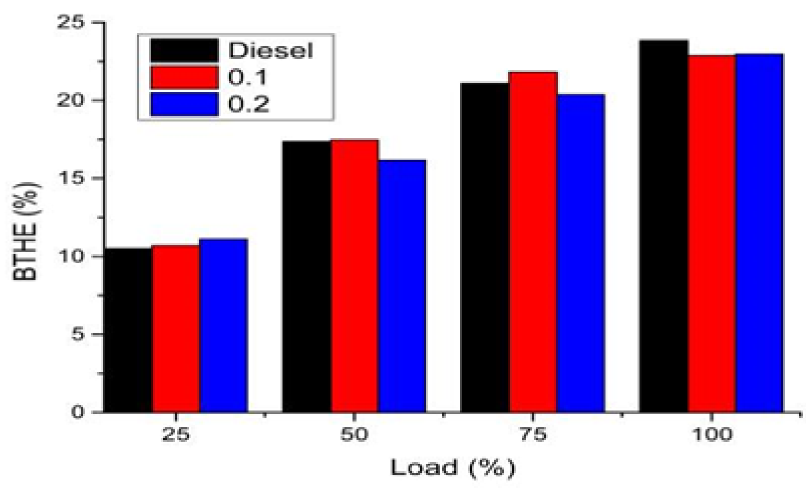

Figure 4: Load Vs Brake thermal efficiency

Emission Characteristics

Unburned Hydrocarbon Emission:

Figure.5 illustrates the trends in unburned hydrocarbon (UBHC) emissions for all biodiesel blends and diesel. The data clearly shows a decrease in UBHC emissions as the percentage of biodiesel in the blend increases. Furthermore, as the engine load increases with both diesel and blends of waste cooking palm oil, there is a notable reduction in UBHC emissions. This reduction can be attributed to the increase in fuel consumption at higher engine loads.

The slight decrease in UBHC emissions observed in the case of B80 compared to diesel indicates improved combustion characteristics of biodiesel blends. Waste cooking palm oil biodiesel, in particular, exhibits a higher oxygen content, which promotes more thorough combustion, contributing to reduced UBHC emissions.

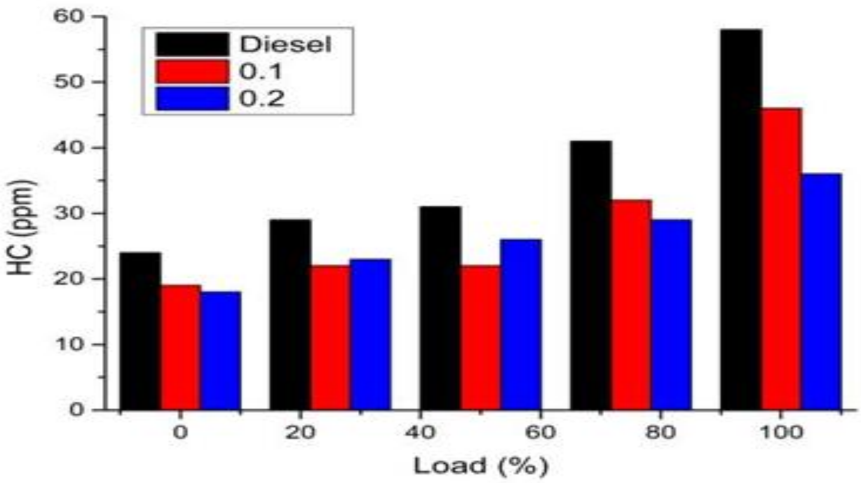

Figure 5: Load Vs HC PPM

Carbon monoxide emission:

Figure.6 provides a comparative analysis of carbon monoxide (CO) emissions between biodiesel and its blends with traditional diesel. CO is an intermediate compound that forms during the combustion of hydrocarbon fuels, and its production is influenced by various factors such as air-fuel equivalence ratio, fuel type, combustion chamber design, injection timing, injection pressure, and engine speed.

The experimental results clearly indicate that the concentration of CO in biodiesel and its blends, specifically B20, B40, B60, and B80, is lower when compared to the emissions from diesel fuel operation. These findings hold consistently across various engine loads. This reduction in CO emissions can be attributed to the higher oxygen content present in biodiesel. This elevated oxygen content facilitates the oxidation of a greater number of carbon molecules during combustion when contrasted with the combustion of diesel fuel.

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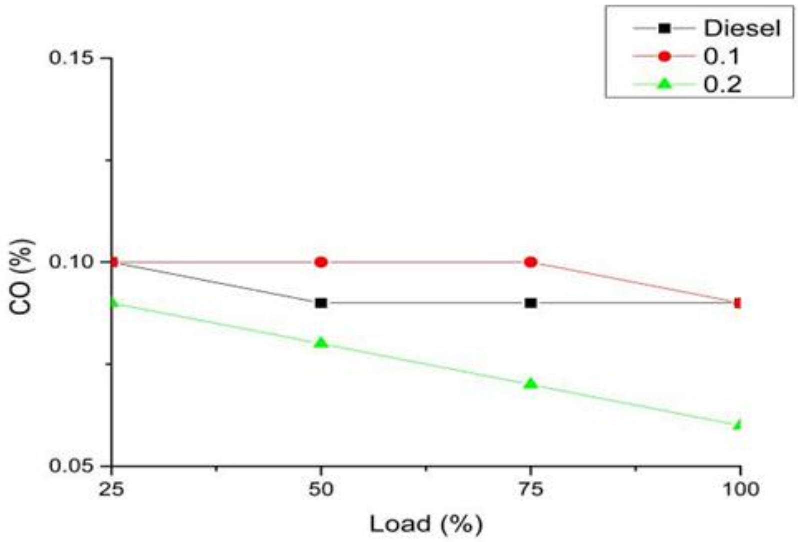

Figure 6: Load Vs CO %Vol

Carbon dioxide emission:

Carbon Dioxide Emission: Figure.7 presents a comparative analysis of carbon dioxide (CO2) emissions between biodiesel and its blends when compared to traditional diesel. CO2 is an intermediate compound that emerges during the intermediate combustion phase of hydrocarbon fuels.

The results show that as the percentage of biodiesel in the blends increases, there is a reduction in CO2 emissions compared to diesel across various load conditions. Notably, B80 exhibits the lowest CO2 emissions when compared to all the tested fuels.

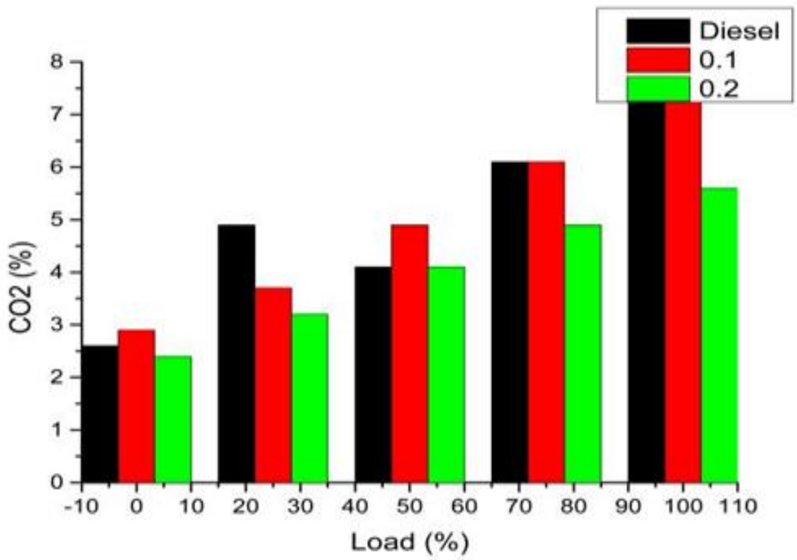

Figure 7: Load Vs CO2 %Vol

Oxides of nitrogen:

Figure.8 illustrates the variation in Nitrogen Oxides (NOx) concentration with load for both biodiesel blends and diesel. The generation of NOx within the cylinder is influenced by factors such as oxygen content, combustion flame temperature, and reaction duration. It is observed that NOx emissions from all biodiesel blends are

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marginally higher compared to those from diesel fuel. Additionally, under full load conditions, the NOx content of B20 is slightly elevated in comparison to that of conventional diesel fuel.

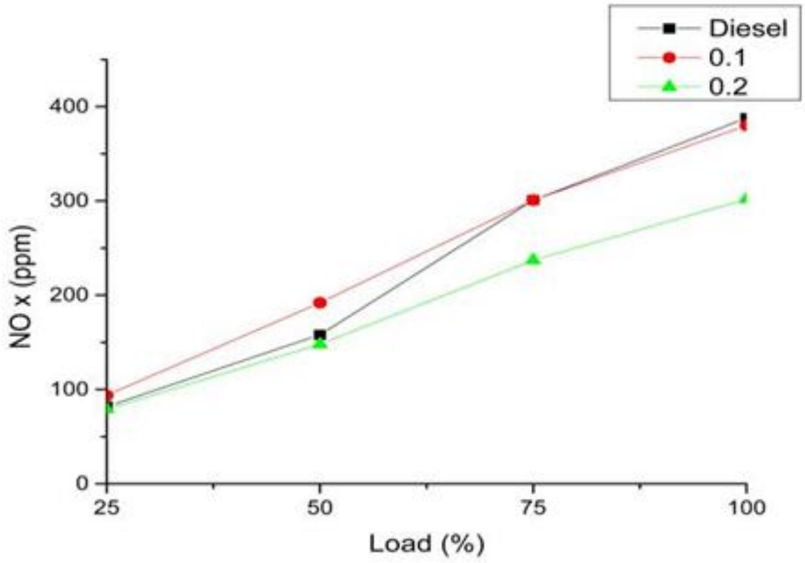

Figure 8: Load Vs NOx(ppm)

Experimental data

INPUTS		Engine performance			Emission characteristics			
LOADS	BLENDS	BP (Kw)	BTE (%)	SFC (kg/kW hr)	HC (ppm)	CO (%)	CO2 (%)	NOX (ppm)
0	0	0.05	1.27	6.70	24	0.08	2.6	44
0	10	0.07	1.51	5.61	19	0.08	2.4	44
0	20	0.05	1.19	6.98	19	0.11	2.9	59
25	0	0.59	10.50	0.81	29	0.1	3.7	82
25	10	0.6	10.70	0.79	22	0.1	3.7	94
25	20	0.63	11.12	0.75	23	0.09	3.2	79
50	0	1.18	17.35	0.49	31	0.09	4.9	158
50	10	1.2	17.46	0.49	26	0.08	4.1	148
50	20	1.22	16.17	0.51	22	0.1	4.9	192
75	0	1.79	21.10	0.4	41	0.09	6.1	301
75	10	1.78	21.83	0.39	29	0.07	4.9	237
75	20	1.79	20.38	0.41	32	0.1	6.1	301
100	0	2.29	23.84	0.36	58	0.09	7.3	388
100	10	2.29	22.86	0.37	36	0.06	5.6	302
100	20	2.3	22.97	0.36	46	0.09	7.4	380

IV. CONCLUSION

The experimentation detailed herein yields a conclusion that leveraging water-emulsified diesel fuel can effectively enhance diesel engine performance and emission profiles. This finding aligns coherently with prior studies on emulsified fuels found in existing literature. Notably, adopting emulsified fuel combustion necessitates no modifications to the engine. However, a potential drawback involves the potential for engine component corrosion over prolonged use, attributed to the presence of water in the emulsion. Counteracting this, Kweonha Park et al., [7] posited that rapid evaporation of water, via micro-explosions, converts it into extremely minute droplets. This phenomenon prevents direct contact of water droplets with the combustion chamber wall, thereby averting cylinder surface corrosion.

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