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Impact of Biodiesel and Antioxidant on Inlet Valve of Compression Ignition Engine

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Abstract

This study investigates the impact of biodiesel and antioxidants on the inlet valve of a compression ignition engine. Biodiesel, derived from sources mustard oil is blended with diesel fuel to create

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biodiesel-diesel blends. Additionally, antioxidants, such as those found in clove oil, are added to the blends to improve their stability and performance. The research aims to address the environmental concerns associated with traditional fossil fuels by exploring the use of alternative fuels like biodiesel. It also seeks to enhance engine performance and durability through the addition of antioxidants, which can mitigate issues such as carbon deposit formation on engine components. Experimental methodologies involve endurance tests conducted on the compression ignition engine using different fuel blends, including pure diesel, biodiesel blends, and biodiesel blends with antioxidant additives. Analysis techniques such as scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) are employed to examine deposit formations on the inlet valve after prolonged engine operation. Results indicate that biodiesel blends with antioxidants exhibit reduced deposition on the inlet valve compared to pure diesel or biodiesel blends without antioxidants.
Keywords: diesel engine, biodiesel, diesel, antioxidant, depositions

Introduction

The effect of graphene oxide nanoparticles (50 ppm) and hydrogen enrichment on the Nerium oleander methyl ester-diesel blend is investigated in the present research study using a compression ignition engine in a dual-fuel mode. Biodiesel is derived from Nerium oleander oil, and 20% (v/v) is blended with 80% of diesel fuel. Following that, Novel carbon-based additives are dispersed in biodiesel–diesel blend and supplied as a piloted fuel (Höök & Tang, 2013). In the recent years, mankind has been witnessing significant changes in the climate conditions. Many countries are struggling to ensure their energy security due to the

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escalating population count and the high energy demand required to sustain economic growth. Globally, over 3.9 billion tons of oil equivalent were produced annually, with an average rate of 85 million barrels per day since 2010. Additionally, 3700 million tons of coal and 2900 million tons of natural gas are also produced (Höök & Tang, 2013; Mengal et al., 2017).

In further, the rapid phase of industrial growth inherently contributes to the depletion of fossil fuels, such as coal and oil reservoirs that are being used in day-to-day human activities. Petroleum fuels are of hydrocarbons, which, upon combustion would release harmful gases like Nitrous oxides (NOx), Methane (CH_4), Carbon Monoxide (CO) (Bhangwar et al., 2024). This emissions coming out as a result of fossil fuel combustion lead to detrimental effects such as glacier melting, heatwaves, and floods (Pandey et al., 2012). adopting alternative fuels to cater for the internal combustion engines would appear as a potential solution to address these alarming environmental issues. Alternative fuel that mimics the properties of petroleum-based fuels started utilizing plastics highly, owing to the huge availability of plastics produced to accompany the expanding population. Khan et al. (2016) reported that the viscosity of waste plastic pyrolysis oil (WPPO) obtained at 425 °C was 1.98 cSt, lower than that of diesel. The densities of waste plastic pyrolysis oil and WPPO50 were found to be 0.7477 g/cc and 0.7943 g/cc, respectively, which closely resemble diesel. The calorific value was found to be 9829.3515 kcal/kg. Thus, the authors suggested to utilize waste plastic oil derived through pyrolysis as an alternative fuel,

Nanofluids are characterized as two-phase fluid mediums containing both solid and liquid components, creating a

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heterogeneous mixture or colloidal suspension of condensed nanomaterials (Yu & Xie, 2012). The solids can be metals, metal oxides, carbons, while liquids include water, oil, and energy fuels. Buonomo et al. (2015) highlighted that nanofluids find applications in various industries like electronics and automobiles due to their superior heat transfer properties when compared to traditional cooling fluids. Researchers mostly recommend the two-step method for nanofluid preparation due to its efficiency, cost-effectiveness, and time-saving benefits (Dey et al., 2017; Yu & Xie, 2012). The addition of CeO_2 nanoparticles into biodiesel has demonstrated positive effects on reducing toxic emissions (soot, smoke opacity, NOx, CO, HC), enhancing thermal efficiency and brake power, and improving fuel consumption (Bhan et al., 2024; Bhangwar & Ghoto, 2024; Hoang, 2021).

Transesterification was used to produce biodiesel from waste cooking oil (WCO). An ultrasonication procedure was used to gradually mingle the nanoparticles with a B20-diesel fuel blend in mass fractions of 50 and 100 ppm (Bhan et al., 2024).

Methodology

In this research; the analysis of depositions of inlet valve of diesel engine. For experimental set-up of compression ignition engine (C.I), different tools/equipment was applied to measure engine emission and particulate matter. The engine performance tests were conducted using selected non-edible oils extracted from mustard and clove oil blended in biodiesel as an antioxidant.

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A diesel engine shown in figure 1 is a type of internal combustion engine that uses the heat of compression to ignite fuel injected into the combustion chamber. Diesel engines are commonly used in automobiles, trucks, buses, locomotives, ships, and power generators. The main components of a diesel engine include the cylinder block, piston, connecting rod, crankshaft, fuel injector, intake and exhaust valves, and turbocharger. When fuel is injected into the combustion chamber, it mixes with the air that has been compressed by the piston. The heat generated by this compression causes the fuel to ignite, which produces a high-pressure explosion that drives the piston downward. Diesel engines are known for their efficiency and durability. They can produce high torque at low speeds, making them ideal for heavy-duty applications such as towing and hauling. However, they can be noisy and emit more pollutants than gasoline engines. Advances in technology, such as the use of particulate filters and selective catalytic reduction systems, have helped to reduce diesel engine emissions in recent years.

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Table 1: Detail of engine used in this research work.

Parameter	Value
Stroke	80 mm
Speed	2600 RPM
Displacement	0.353 L
Compression ratio	21-23
Mean effective pressure	576 kPa
Piston mean speed	6.93m/s
specific fuel consumption	278.8 g/kWh
Specific oil consumption	4.08 g/kWh
Cooling water consumption	1360 g/kWh
Injection pressure	14.2+0.5 Mpa
Valves clearance	Inlet valve 0.15-0.25 mm
Maximum engine power	7.7 kW
Maximum engine torque	80 Nm

Carbone Depositions Analysis of Engine Parts

In this study, an endurance test was performed for 100 hours at 1500 rpm with a constant load. Three samples of fuels: DF (diesel fuel), B30 (30% mustard biodiesel and 70% DF), and biodiesel blended fuel with 3000 ppm in engine. The use of 30% biodiesel in diesel fuel (B30) for the endurance test was based on what was considered a good mix. The engine was run for eight hours after being started for 15 minutes each day with diesel fuel during the test. The injector nozzle was photographed for a visual inspection to determine the effect of using DF and biodiesel blends during the endurance test. SEM and energy dispersive X-ray spectroscopy (EDS) were used to examine deposit formations at and around the inlet valve in a variety of locations, as depicted in figure 2. Figure 2 depicts the equipment used for energy dispersive X-ray

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spectroscopy (EDS) and scanning electron microscopy (SEM) analysis. The engine was put through a 100-hour endurance test using DF, B30, and clove oil (3000 ppm), respectively, after being partially disassembled and subjected to inlet deposit formation studies using SEM-EDS analysis.

Figure 2 JEOL JSM-6490 LV for SEM-EDS analysis

To begin the procedure, a conductive double-sided carbon solution tape was used to mount the sample stub in the sample chamber of a JEOL JSM-6490 LV Scanning Electron Microscope. This apparatus was also equipped with a Bruker EDS (Energy Dispersive X-Ray Spectrometer), which is an important accessory component. The SEM was set to suitable operational parameters to achieve fine focusing and high magnifications of the samples. Photomicrographs were taken of selected positions for study and

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interpretation. After the imaging, the elemental composition of the samples was determined using the EDS.

In this study, an endurance test was performed for 100 hours at 1500 rpm with a constant load. Three samples of fuels: DF (diesel fuel), B30 (30% mustard biodiesel and 70% DF), and biodiesel blended fuel with 3000 ppm in engine. The use of 30% biodiesel in diesel fuel (B30) for the endurance test was based on what was considered a good mix. The engine was run for eight hours after being started for 15 minutes each day with diesel fuel during the test. The inlet valve was photographed for a visual inspection to determine the effect of using DF and biodiesel blends during the endurance test. SEM and energy dispersive X-ray spectroscopy (EDS) were used to examine deposit formations at and around the inlet valve in a variety of locations, as depicted in figure 3. 18 to find out how Df, biodiesel blends, and biodiesel mixed with clove oil affect the engine Figure 3.18 depicts the equipment used for energy dispersive X-ray spectroscopy (EDS) and scanning electron microscopy (SEM) analysis. The engine was put through a 100-hour endurance test using DF, B30, and clove oil (3000 ppm), respectively, after being partially disassembled and subjected to injector deposit formation studies using SEM-EDS analysis

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Results and Discussion

Deposition of Engine Inlet Valve

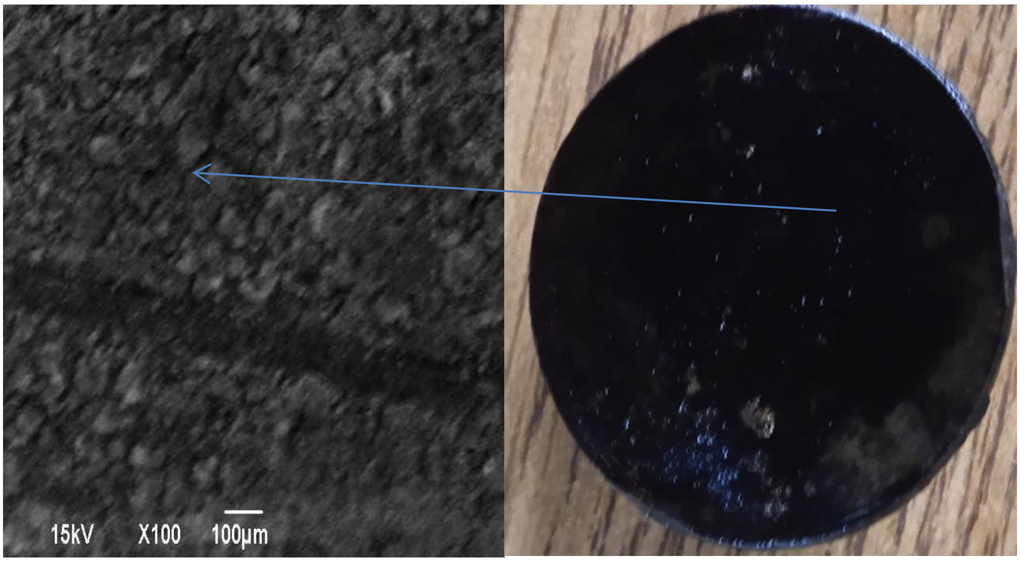

Figure 3 : SEM analysis of inlet valve at D100

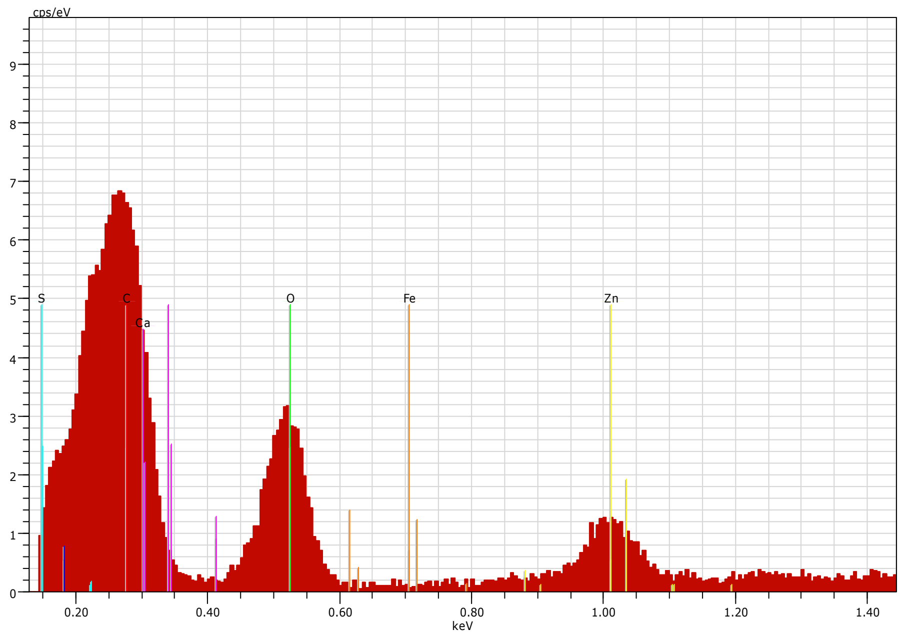

Figure 4 EDX analysis of inlet valve at D100

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Table 2 Quantitative Analysis of Inlet Valve D100

Element	Series	unn. C	norm. C	Atom. C	Error
		[wt.%]	[wt.%]	[at.%]	[%]
Carbon	K-series	31.63	32.65	47.53	4.5
Oxygen	K-series	34.68	35.80	39.13	5.5
Phosphorus	K-series	2.73	2.82	1.59	0.1
Sulfur	K-series	7.22	7.46	4.07	0.3
Calcium	K-series	10.63	10.97	4.79	0.4
Zinc	K-series	7.05	7.27	1.95	0.5
Iron	K-series	2.93	3.03	0.95	0.2
	Total:	96.87	100.00	100.00	

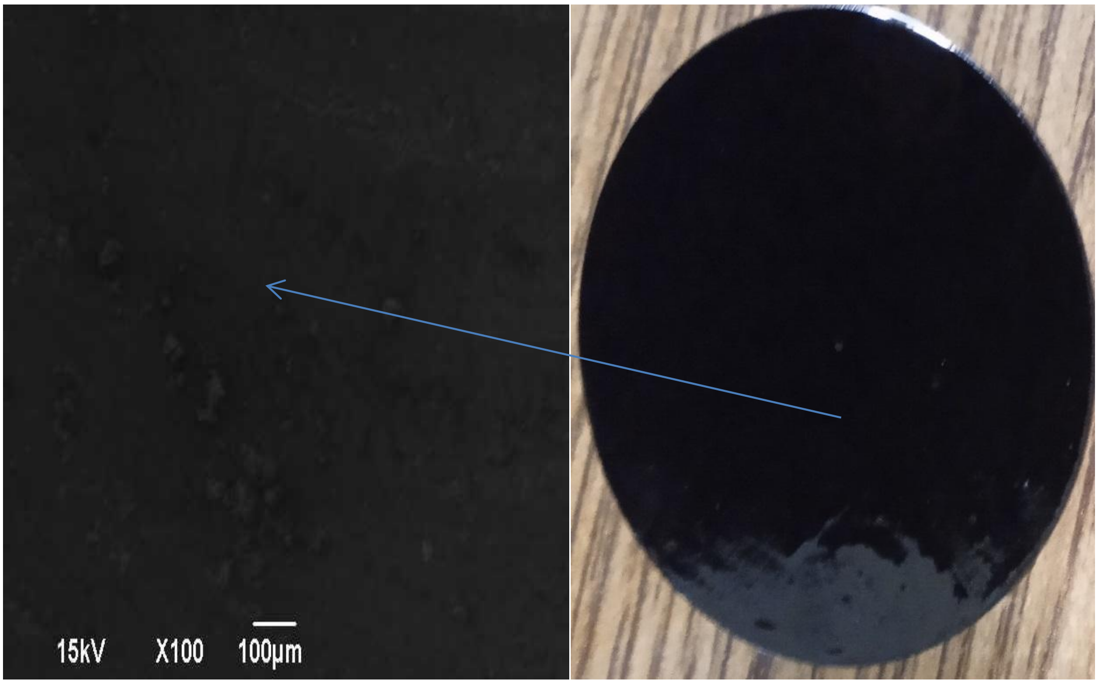

Figure 4 : SEM analysis of inlet valve at B30

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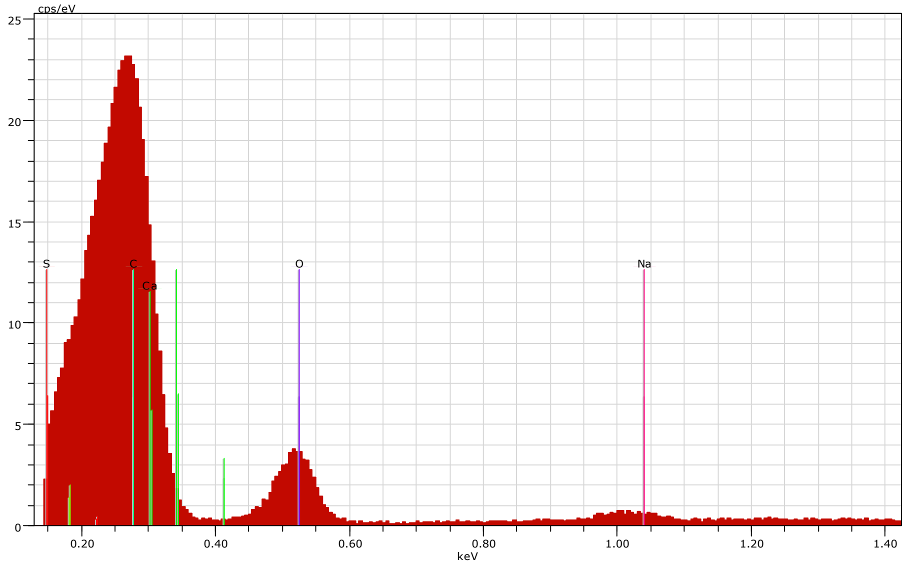

Figure 5 : EDX analysis of inlet valve at B30

Table 3 Quantitative Analysis of Inlet Valve B300

Element	Series	unn. C	norm. C	Atom. C	Error
		[wt.%]	[wt.%]	[at.%]	[%]
Carbon	K-series	55.42	55.42	64.83	17.6
Oxygen	K-series	35.87	35.87	31.50	11.9
Sodium	K-series	1.28	1.28	0.78	0.1
Phosphorus	K-series	0.94	0.94	0.42	0.1
Sulfur	K-series	2.17	2.17	0.95	0.1
Calcium	K-series	4.32	4.32	1.51	0.2
	Total:	100.00	100.00	100.00	

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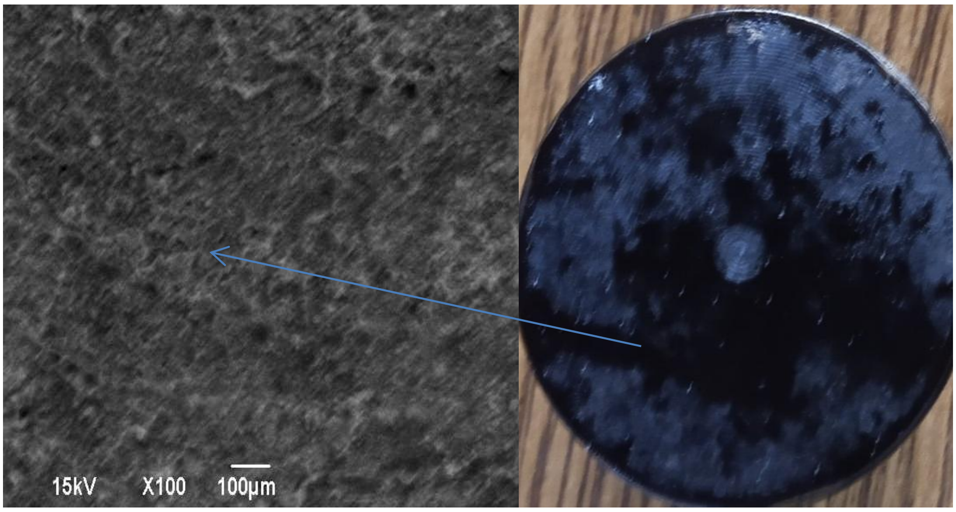

Figure 6: SEM analysis of inlet valve at CL3000ppm

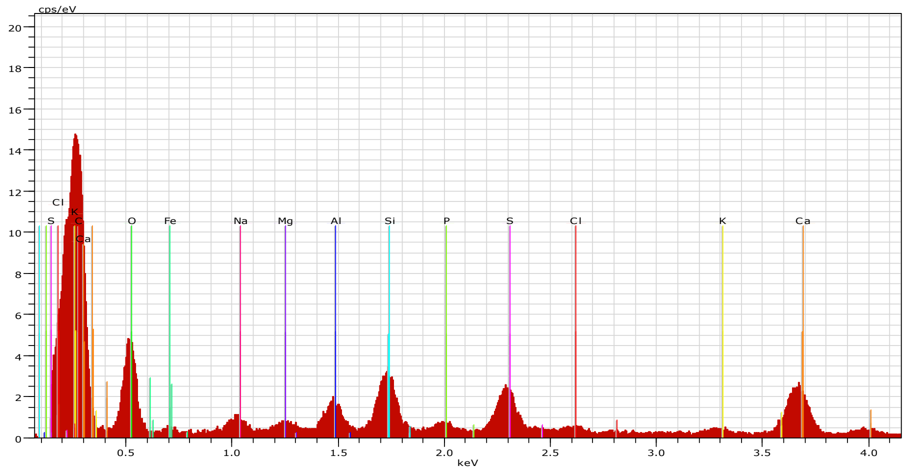

Figure 7: EDX analysis of inlet valve at CL3000PPM

Table 4 Quantitative Analysis of Inlet Valve Cl3000ppm

Element	Series	unn. C	norm. C	Atom. C	Error
		[wt.%]	[at.%]	[wt.%]	[%]
Carbon	K-series	28.63	28.63	38.83	34.4
Oxygen	K-series	50.96	50.96	51.89	17.3
Aluminium	K-series	1.33	1.33	0.80	0.1
Silicon	K-series	2.89	2.89	1.68	0.2
Sulfur	K-series	2.64	2.64	1.34	0.1
Potassium	K-series	0.69	0.69	0.29	0.1

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Calcium	K-series	5.59	5.59	2.27	0.2
Iron	K-series	4.90	4.90	1.43	0.2
Magnesium	K-series	0.42	0.42	0.28	0.1
Sodium	K-series	1.09	1.09	0.77	0.1
Phosphorus	K-series	0.42	0.42	0.22	0.0
Chlorine	K-series	0.45	0.45	0.21	0.0
	Total:	100.00	100.00	100.00	

According to the results, all three fuels caused the deposition of aromatic compounds on the engine inlet valve surface during the endurance test. The analysis using the energy-dispersive X-ray method showed that clove oil fuel had the highest deposition of aromatic compounds, followed by biodiesel blended fuel and diesel. The deposition percentages on D100, B30, and CL3000 were 55.42%, 31.63%, and 28.63%, respectively. The biodiesel blend fuel had higher deposition compared to diesel, but adding clove oil to the blend reduced the deposition compared to biodiesel and diesel fuel samples on the inlet valve of the engine.

Carbon deposit formation is a complex issue in diesel engines, caused by a reaction among fuel, blow-by gases, and lubricant oil. Fuel is the primary source of carbon deposit, with lubricant oil contributing a smaller portion. This deposit negatively impacts the combustion process. Despite the challenges in analyzing carbon deposit in diesel engines due to varying engine sizes, technologies, and test conditions, this study referred to similar research to determine the best analysis approach. The study used macroscopic and microscopic analyses to examine carbon deposit formation on the exhaust valve after a 100-hour durability test. Carbon deposited was the heterogeneous mixture of carbon

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excess, carbonaceous combinations, and oxygenated resinous organic material resulting from incomplete combustion.

The figure 3-7 showed white dusts on the exhaust from carbon deposit in D100, B30, and CL (3000ppm) engines, possibly from surfactant oxidation. The microscopic observation revealed that carbon deposit structure in B30 and D100 engines is blacker and softer, with metals and other elements found in all engines, mostly in B30 engines. Carbon deposits on the top of the exhaust valve of B30-fueled engines are higher than those in mineral diesel and clove oil. Scanning electronic microscopy (SEM) and energy dispersive microscopy (EDX) analysis of piston head deposition in biodiesel, diesel, and clove oil showed that biodiesel has a higher carbon deposition due to poor lubricant quality and incomplete combustion during engine operation.

References

Bhan, S., Gautam, R., & Singh, P. (2024). Analyzing the impact of adding aluminum oxide and cerium oxide nanoparticles to waste cooking biodiesel on engine performance, combustion and emissions characteristics. *Petroleum Science and Technology*, *42*(6), 706-734.

Bhangwar, S., & Ghoto, S. M. (2024). ANALYSIS OF EMISSION OF COMPRESSION IGNITION ENGINE USING BIODIESEL AS ADDITIVE. *Kashf Journal of Multidisciplinary Research*, *1*(10), 50-55.

Bhangwar, S., Luhur, M. R., Walasai, G. D., & Alghamdi, T. A. (2024). Impact of mustard biodiesel and clove oil additives on particulate matter emission and carbon deposition in diesel engines. *Frontiers in Energy Research*, *12*, 1395545.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Buonomo, B., Manca, O., Marinelli, L., & Nardini, S. (2015). Effect of temperature and sonication time on nanofluid thermal conductivity measurements by nano-flash method. *Applied Thermal Engineering*, *91*, 181-190.

Dey, D., Kumar, P., & Samantaray, S. (2017). A review of nanofluid preparation, stability, and thermo-physical properties. *Heat Transfer—Asian Research*, *46*(8), 1413-1442.

Hoang, A. T. (2021). Combustion behavior, performance and emission characteristics of diesel engine fuelled with biodiesel containing cerium oxide nanoparticles: A review. *Fuel Processing Technology*, *218*, 106840.

Höök, M., & Tang, X. (2013). Depletion of fossil fuels and anthropogenic climate change—A review. *Energy policy*, *52*, 797-809.

Khan, M., Sultana, M., Al-Mamun, M., & Hasan, M. (2016). Pyrolytic waste plastic oil and its diesel blend: fuel characterization. *Journal of environmental and public health*, *2016*(1), 7869080.

Mengal, G., Harijan, K., Uqaili, M. A., & Mirjat, N. H. (2017). Mitigation of GHG emissions with a 50 MW wind power plant: a case study of Pakistan. *Sindh University Research Journal (Science Series)*, *49*(1), 49-54.

Pandey, R. K., Rehman, A., & Sarviya, R. (2012). Impact of alternative fuel properties on fuel spray behavior and atomization. *Renewable and Sustainable Energy Reviews*, *16*(3), 1762-1778.

Yu, W., & Xie, H. (2012). A review on nanofluids: preparation, stability mechanisms, and applications. *Journal of nanomaterials*, *2012*(1), 435873.