Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X
Volume 3, Issue 7, 2025

ANALYZING CARBON DEBRIS AND ENGINE WEAR IN SINGLE CYLINDER DIESEL ENGINE

Faheem Ahmed Solangi[*1], Altaf Alam Noonari[2], Abid Ali Khaskheli[3], Tarique Ahmed Memon[4], Aisha Hafeez[5]

[*1,3]*Department of Mechanical Engineering QUEST, Nawashah, Sindh, Pakistan.*
[2]*Department of Environmental Sciences, Aror University of Art, Architecture, Design and Heritage, Rohri, Sukkur, Sindh, Pakistan.*
[4]*Department of Mechanical Engineering, The University of Larkano, , Sindh, Pakistan*
[5]*Department of Industrial and Manufacturing Engineering, Quaid-e-Awam University of Engineering Science & Technology Nawabshah, Sindh, Pakistan*

[4]tariquememon@uolrk.edu.pk

DOI: https://doi.org/10.5281/zenodo.16810222

Keywords

Article History
Received: 19 May, 2025
Accepted: 01 August, 2025
Published: 11 August, 2025

Corresponding Author: *
Faheem Ahmed Solangi

Abstract

In this investigation, three fuel samples—PD100, (2) D96-Bu4 (96%vol. diesel Bu4%vol. N-butanol), and (3) D96-Pn4 (96%vol. diesel, 4%vol. N-pentanol)—were put through endurance test in a single-cylinder CI engine. The results of the study showed that during tests on all gasoline samples, visual inspection showed minor deposits on the engine head. SEM tests revealed that the D96-Bu4 engine had higher carbon deposits on and around the engine head surface than the engine running with DF.Nonetheless, there was less carbon buildup in the ternary mix D96-Pn4. Currently, n-pentanol, diesel, and leftover cooking oil were used to create fuel mixes. When compared to PD, the wear debris concentration was reduced by emulsion fuel in the binary blend, even when n-pentanol was added as a ternary blend D96-Pn4 for aluminum (Al), calcium (Ca), and cadmium (Cd). Ultimately, the viscosity and density readings decreased when the engine was run on both blend fuels.

INTRODUCTION

The global economy is increasingly reliant on energy sources to transport people and things as a result of globalization. Diesel engines are considered prime movers because to their excellent thermal efficiency, heavy-duty operation, and exceptional stability. [1]. Diesel engines' unmatched efficiency in converting fuel into power, dependability, durability, and torque capacity make them indispensable in the locomotive, agricultural, construction, and industrial sectors [2]. Because of their widespread use, emerging countries like India are becoming more and more reliant on imports to meet their fuel needs, which hurts their economies and makes them more reliant on fossil fuels [3]. It is commonly recognized that diesel engines' excessive NOx and smoke emissions are harmful to the environment and all living beings [4]. The economy and environment will benefit from even a small switch to renewable biofuel from fossil fuels [5]. In CI (compression ignition) engines, blending n-butanol and n-pentanol with diesel fuel can have a number of consequences on emissions and engine performance. These alcohols can generally enhance some elements of combustion.In a lubrication system, wear particles remain suspended in the lubricating fluid. After a certain amount of operation, variations in the concentrations of

metallic particles in the lubricating oil may be investigated and evaluated to offer adequate information about the wear rate, element source, and engine condition [6]. Among the components of diesel engines that typically wear out are the cylinder liner, bearing, cam, tappet, crankshaft journals, pistons and piston pins, valve guides, valve systems, and so on [7].
The primary goal of this work is to compare the emission data, engine fuel economy, lubricating oil analysis, and exhaust valve surface deposits for the PD100, D96-Bu4, and D96-Pn4 blends, respectively.

2. Materials and Experimental Methodologies

2.1.1. Fuel Formulation

2.1.2. The proper blend was produced using a mechanical homogenizer that rotated at 4000 revolutions per minute. Figure 1 shows the physical location of the fuel prior to combining.

Fig.1. Appearance of selected fuels for experiments.

The fuel characterization for the three test fuels—PD, D96-Bu4, and D96-Pn4—is displayed in Table 1.

Table 1. Fuel characterization.

Properties	D100	D96-Bu4	D96Pn4	Test Method
Calorific valve MJ/Kg	42.5	39	40	ASTM D-240
Viscosity 40 °C Cst	2.28	2.34	1.95	ASTM D-88
Density g/ml	0.85	0.89	0.84	ASTM D-854
Flash point °C	78	85	94	ASTM D-92
Cetane number	50	53	55.5	ASTM D-4737

2.1.3. Engine test bed

A water-cooled, four-stroke, single-cylinder, compression ignition engine connected to an eddy current dynamometer was used for the experiments. The main requirements for compression ignition engine is also listed in Table 2.

Table 2. Engine specifications

Model	Single-Cylinder, Horizontal, water cooledfour stroke pre-combustion chamber
Bore	75mm
Stroke	80mm
Output (12 hours rating)	4.4kW/2600r/min
Displacement	0.353L
Compression ratio	21-23
Specific fuel consumption	278.8 g/kW h
Cooling water consumption	1360 g/kW h

Specific oil consumption	4.08 g/kW h
Injection pressure	14.2 + 0.5 MPa

Tests were conducted on each fuel sample as part of the investigation. After the engine was disassembled to remove the engine head for analysis, the three remaining test fuels were used in the same manner. Finally, scanning electron microscopy (SEM) was used to analyze each engine head sample that was collected. Deposits at both the macro and submicron scales can be examined using SEM. To investigate the effects of PD100, D96-Bu4, and D96-Pn4 mixtures on engine oil, lubricant oil samples were collected every 20 hours for each fuel sample during the engine endurance test.

3. Results and discussion

3.1 Engine head deposition

The main parts of diesel engines are exposed to high temperatures and mechanical stresses. Deposits also develop on these parts as a result of oxidative and thermal lubricant deterioration, incomplete or pyrolysis combustion, and lubricant degradation. In addition to increasing maintenance costs, these deposits affect engine performance, efficiency, and operation. Large deposits may cause engine failure [8]. Carbon is created as a byproduct of burning fuel. Carbon deposition is caused by both incomplete fuel combustion and trace amounts of lubricating oil pollutants. The accumulation reduces the engine's service life [9]. For this study, the carbon deposits on engine heads were photographed and assessed. In contrast to petroleum diesel, Figure 2 shows that a thick carbon deposit was found on the D96-Bu4's engine head when it was used in damp and unclean conditions. Degradation and the evaporation of the lighter fraction fuel content could be the cause of this. The D96-Pn4 engine has a lower carbon deposit. There may be less cleaner deposition when burning D96-Pn4 cleaner in an environment with higher oxygen concentrations. However, test fuel D96-Pn4 showed less deposition, as shown in figure 2.

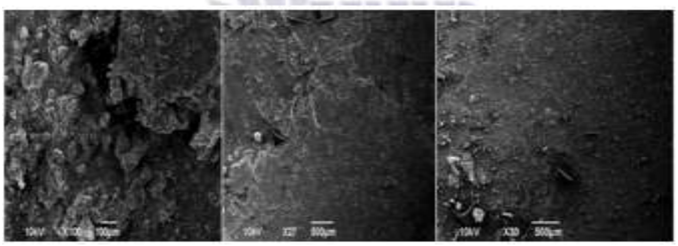

Fig. 2. SEM pictures of PD, D96-Bu4 and D96-Pn4.

3.2 Engine wear

During endurance testing, the quantity of metallic particles in engine oil provides crucial information about the element's origin and wear rate. Therefore, a metal analysis of the lubricating oil can be used to reasonably estimate the amount of wear that has occurred on the engine's essential components. As a result, it is possible to forecast the engine's condition at that time [10]. Cadmium (Cd) comes from the cylinder liner, compression rings, gears, crankshaft, and bearing; aluminum (Al) comes from the piston or dust ingestion; copper (Cu) comes from the bearings and bushings; lead (Pb) comes from the bearings, paints, and grease; and magnesium (Ca) comes from the bearings, bushings, and lubricants [11]. A diesel engine's wear rate, element source, and engine condition can all be precisely predicted by looking at the quantity of metallic particles in the lubricating fluid [12]. A single-cylinder diesel engine underwent an endurance test to determine different facets of lubricating oil characteristics and wear estimation [13]. Each element's hollow cathode lamp was placed separately in an Atomic Absorption Spectrophotometer (AAS) to measure engine analysis wear and debris. Standard solutions were created with elements like nickel (Ni), copper (Cu), and iron (Fe). The engine ran on PD, D96-Bu4, and D96-Pn4 fuels during the trials.

3.2.1 Aluminum (Al)

The corrosion and wear of different engine parts, including the cylinder liner, valves, bearings, piston rings, and their guides, are the causes of the aluminum metal particles that have accumulated in the old lubricating oil in the engine sump.

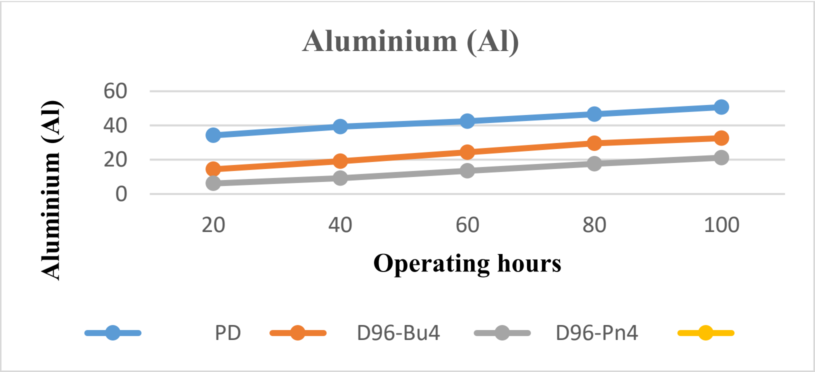

Fig.3. Aluminum Concentration v/s operating hours.

Figure 3 makes it evident that the rate of iron growth is higher in D96-Bu4 and DF fuel. The amount of aluminum in the lubricant oil drained from the engine running on the mix fuel D96-Pn4 was lower than that of the diesel-powered engine.

3.2.2 Calcium (Ca)

according to the analysis of wear debris. Fig. 4 displayed the concentration of copper in binary and ternary blends of pure diesel, such as D96-Bu4 and D96-Pn4 fueled engines, with respect to the number of hours after every 20 hours that lubricating oil was consumed. It was evident from the figure that a binary blend produces a higher proportion of copper. However, adding n-pentanol as a binary blend resulted in little change when compared to PD.

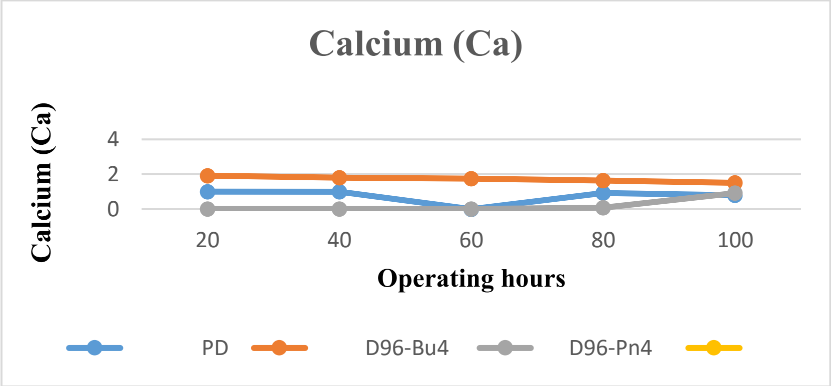

Fig.4. Calcium Concentration v/s operating hours.

Figure 4 shows the diesel engine with less copper wear using the D96-Pn4 fuel blend. The binary D96-Bu4 and PD combination has the highest copper concentration. However, the computer regarded the binary mixture D96-Pn4 as approximately non-detectable because of its incredibly low or negligible concentrations.

3.3.3 Cadmium (Cd)

Many components, such as shafts, cams, rods, springs, valves, and valve guides, contain cadmium. The results are shown in relation to the dominant cadmium metal concentration in the lubricating oil in Figure 5.

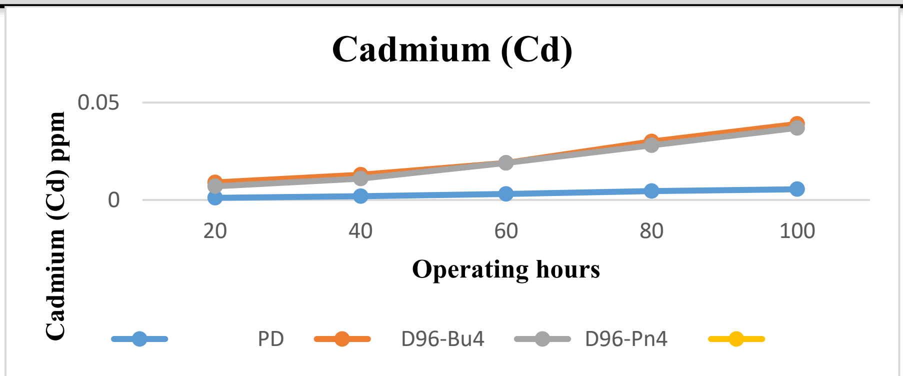

Fig.5. Cadmium Concentration v/s operating hours.

Figure 5 shows that when an engine is powered by a blend of D96-Pn4 and diesel fuel, the amount of cadmium element is only slightly at its lowest level. However, in this instance, diesel fuel was found to be inferior to the binary blend (D96-Bu4).

4. Conclusions

This study examined the effects of PD100, D96-Bu4, and D96-Pn4 mix fuels on head surface deposits and engine wear through trials. The following conclusions could be made in light of the experimental findings:

In contrast to oily or greasy deposits when it was running with PD100 and D96-Bu4, the engine head displayed dry deposits when it was fueled with D96-Bu4.After testing, the D96-Pn4 blend had significantly fewer engine head surface deposits than the D96-Bu4 blend, according to the SEM analysis. The carbon layer became unevenly thick as a result of the deposition.

However, SEM tests revealed dry, dark deposits on and around the engine head area when the engine was powered by the D96-Bu4 blend.These deposits blocked the area in some way or were entirely covered. The darker regions had a higher carbon concentration. • D96-Bu4 fuel was responsible for a considerable amount of deposits. More specifically, using D96-Bu4 resulted in an overly wet exhaust valve. This could be explained by the fact that the D96-Bu4 deposits became wet and brittle because the injected fuel would not dry when it hit the valve surface wall. analysis of the engine's wear and debris. We investigated iron aluminum (Al), cadmium (Cd), and calcium (Ca). the wear particles present in engine lubricant. Compared to D96-Pn4 and PD100, D96-Bu4 was found to have a higher metal concentration.

References

[1] Solangi, F. A., Memon, L. A., Samo, S. R., Luhur, M. R., Bhutto, A. A., & Ansari, A. M. (2024). Analysis of lubricant oil degradation and sound pressure level for CI engine using blend fuels. *Jurnal Teknologi (Sciences & Engineering)*, 86(4), 131-137.

[2] Damodharan D, Sathiyagnanam AP, Rana D, Kumar BR, Saravanan S. Combined influence of injection timing and EGR on combustion, performance and Emission of DI diesel engine fueled with neat waste plastic oil. Energy Convers Manage2018; 161:294–305.

[3] Rajesh Kumar B, Saravanan S. Effects of iso-butanol/diesel and n-pentanol/diesel blends on performance and emissions of a DI diesel engine under Premixed LTC (low temperature combustion) mode. Fuel 2016; 170:49–59.

[4] Rajesh Kumar B, Saravanan S, Rana D, Anish V, Nagendran A. Effect of a sustainable bio fuel – n- Pentanol on the combustion, performance and emissions Of a DI diesel engine under naturally octanol aspirated and exhaust gas recirculation (EGR) modes.Energy Convers Manage 2016; 118:275–86.

[5] Gopal K, Sathiyagnanam AP, Rajesh Kumar B, Saravanan S, Rana D,Sethuramasamyraja B.Prediction of emissions and performance of a diesel engine fueled with n-octanol/diesel blends using response surface methodology. J Cleaner Prod 2018; 184:423–39.

[6] Haseeb ASMA, Fazal MA, Jahirul MI, Masjuki HH. Compatibility of automotive materials in biodiesel: a review. Fuel 2011;90:922–31.

[7] Acharya, S. K., R. K. Swain, M. K. Mohanty, and A. K. Mishra.2014. Preheated and blended karanja oil as diesel engine fuel. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects36 (12):1325–34. Taylor &Francis.

[8] Hoang, A. T., and A. T. Le.2018. A review on deposit formation in the injector of diesel engines running on biodiesel. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects41 (5):584–99.

[9] Yaman, H., & Yesilyurt, M. K. (2021). The influence of n-pentanol blending with gasoline on performance, combustion, and emission behaviors of an SI engine. *Engineering Science and Technology, an International Journal*, *24*(6), 1329–1346.https://doi.org/10.1016/j.jest tch.2021.03.009.

[10] Li, J.; Yu,W.; Yang,W. Evaluating performance and emissions of a CI engine fueled with n-octanol/diesel and n-butanol/diesel blends under different injection strategies. Fuel **2021**,284,19085.

[11] Sudan Reddy Dandu, M., & Nanthagopal, K.(2021). Clean Karanja methyl ester compatibility study on long term tribological behavior of a compression ignition engine. *Fuel*, *291*(January), 120148.

[12] Manieniyan, V., Senthilkumar, R. and Sivaprakasam, S., (2015). Comparative wear analysis in a diesel engine using diesel and biodiesel. *International Journal of Modern Trends in Engineering.*

[13] Solangi, F. A., Memon, L. A., Samo, S. R., Luhur, M. R., Bhutto, A. A., & Ansari, A. M. (2024). Analysis of lubricant oil degradation and sound pressure level for CI engine using blend fuels. *Jurnal Teknologi (Sciences & Engineering)*, *86*(4), 131-137.