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# Alcohol Blends for Experimental Investigation of Noise Emission and Deposit Accumulations in Diesel Engine

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## ABSTRACT

In this experimental study, three fuel samples—PD100, D95Bu5 (95%vol. diesel Bu5%vol. N-butanol), and D95Pn5 (96%vol. diesel, 4%vol. N-pentanol)—were tested for endurance in a single-cylinder CI engine as part of this inquiry. The study's findings demonstrated that small deposits on the engine head were visible upon visual inspection of all gasoline samples tested. Compared to the engine running with DF, the D95Bu5 engine exhibited more carbon deposits on and around the engine head surface, according to SEM examinations. However, the binary mix D95Pn5 showed less carbon accumulation. At the moment, fuel blends were made from residual diesel, n-butanol and n-pentanol. When compared to DF, the deposit concentration was reduced by emulsion fuel in the binary blend, even when n-pentanol was added as blend D95Pn5 for aluminum (Al), calcium (Ca), and cadmium (Cd). Concentrations were further reduced.



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## 1. Introduction

As a result of globalization, the world economy depends on energy sources to transport people and goods. Diesel engines are regarded as prime movers due to their remarkable stability, heavy-duty operation, and high thermal efficiency (Solangi et al., 2024). This combination of efficiency, dependability, durability, and torque capacity makes them essential across the locomotive, agricultural, construction, and industrial sectors (Damodharan et al., 2018). The extensive use of fuel in emerging nations like India is driving a growing reliance on imports, a trend that simultaneously harms their economies and deepens their dependency on fossil fuels (Sun et al., 2025). The release of high levels of NOx and smoke from diesel engines are known to be detrimental to the environment and all living things (Rajesh Kumar & Saravanan, 2016; Wang et al., 2024). Even a modest transition from fossil fuels to renewable biofuel will have positive effects on the economy and environment (Gopal et al., 2018). The incorporation of n-butanol and n-pentanol into diesel fuel can influence both emissions and engine performance in CI (compression ignition) engines in several ways. In general, these alcohols can improve certain aspects of combustion. Wear particles stay suspended in the lubricating fluid in a lubrication system. To provide sufficient information about the wear rate, element source identification, and monitoring engine health, the lubricating oil may be analyzed for changes in metallic particle content after a certain amount of engine operation (Haseeb et al., 2011). Diesel engine components prone to wear consist of the cylinder liner, cam, bearings, tappet, pistons and piston pins, crankshaft journals, valve guides, valve systems (Acharya et al., 2014). This work's main objective is to compare the PD100, D95Bu5, and D95Pn5 blend's respective emission data, engine fuel economy, lubricating oil analysis, and exhaust valve surface deposits.

## 2. Materials and Experimental Methodologies

### 2.1. Fuel Formulation

An apparatus that rotated at 4000 revolutions per minute was used to create the right blend. The fuel's actual location before combining is depicted in Figure 1.


**Figure 1: Appearance of Selected Fuels for Experiments**

Table 1 shows the fuel characterization for the three test fuels: PD, D95Bu5, and D95Pn5.

**Table1**
***Comparative Fuel Characterization of Various Samples***

| Properties | D100 | D95Bu5 | D95Pn5 | Test Method |
|---|---|---|---|---|
| Calorific valve MJ/Kg | 42.5 | 39 | 41 | ASTM D-240 |
| Viscosity 40°C | 2.28 | 2.34 | 3.5 | ASTM D-88 |
| Density | 0.85 | 0.89 | 0.87 | ASTM D-854 |
| Flash Point °C | 78 | 85 | 75 | ASTM D-92 |
| Cetane Number | 50 | 53 | 54 | ASTM D-4737 |

### 2.2. Engine Test Bed

The experiments were performed using a four-stroke, single-cylinder, compression ignition engine that was water-cooled and connected to an eddy current dynamometer. Table 2 presents the main specifications of this engine.

As part of the investigation, tests were performed on every fuel sample. The three remaining test fuels were used in the same way after the engine was disassembled to remove the engine head for analysis. Lastly, every engine head sample that was gathered was examined using scanning electron microscopy (SEM). SEM techniques have been utilized to know the deposit accumulations on exhaust valve surface.

**Table2**
***Main Specifications of the Engine***

| **Model** | **Single-cylinder, water cooled, four strokes, horizontal pre-combustion chamber** |
|---|---|
| Stroke | 80mm |
| Bore | 75mm |
| Output (12 hours rating) | 4.4kW/2600r/min |
| Displacement | 0.353L |
| Compression ratio | 21-23 |
| Specific fuel consumption | 278.8g/kWh |
| Cooling water consumption | 1360 g/kWh |
| Specific oil consumption | 4.08g/kWh |
| Injection pressure | 14.2 + 0.5 MPa |

## 3. Results and discussion

### 3.1. Exhaust Valve

The major components of diesel engines operate under extreme conditions of high temperature and mechanical strain. Under these conditions, several factors including incomplete combustion, fuel pyrolysis, and oxidative and thermal deterioration of lubricants lead to the formation of harmful deposits on engine parts. Such deposits negatively affect engine performance and efficiency, while increasing maintenance expenses. Severe accumulation may lead to engine failure (Hoang & Le, 2019). Burning fuel produces carbon as a byproduct. Both incomplete fuel combustion and trace levels of lubricating oil pollutants contribute to carbon deposition. The engine's service life is shortened by the accumulation (Yaman & Yesilyurt, 2021). The carbon deposits on engine heads were photographed and evaluated for this study. Unlike petroleum diesel, Figure 2 demonstrates that when the D95Bu5 was used in damp and dirty conditions, a thick carbon deposit was discovered on the engine head. This may be due to evaporation and degradation of the lighter fraction fuel content. The carbon deposit is lower in the D95Pn5 engine. Burning D95Pn5 cleaner in an environment with higher oxygen concentrations may result in less clean deposits. But as figure 2 illustrates, test fuel D95Pn5 displayed less deposition.

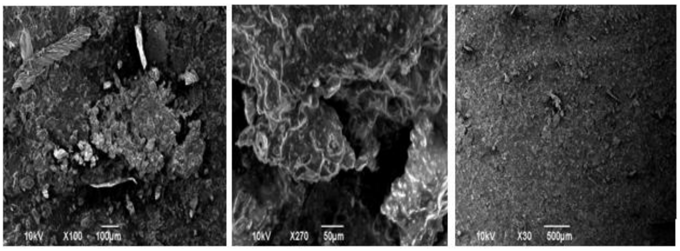


**Figure 2: SEM pictures of PD, D95Bu5 and D95Pn5**

### 3.2. Scanning Electron Microscopy

Diesel engines' major components are subjected to high temperatures and mechanical strains. Incomplete or pyrolysis combustion, oxidative and thermal lubricant deterioration, and lubricant degradation also cause deposits to form on these parts (Li et al., 2021). These deposits impact engine operation, efficiency, and performance in addition to raising maintenance expenses (Dandu & Nanthagopal, 2021). Engine failure may result from large deposits (Manieniyan et al.). Burning fuel produces carbon as a byproduct. Both incomplete fuel combustion and trace levels of lubricating oil pollutants contribute to carbon deposition. The engine's service life is shortened by the accumulation (Li et al., 2019). The carbon deposits on engine heads were photographed and evaluated for this study. Unlike petroleum diesel, Figure 2 demonstrates that when the D95Bu5 was used in damp and dirty conditions, a thick carbon deposit was discovered on the engine head. Degradation and the evaporation of the lighter fraction fuel content could be the cause of this. The D95Pn5 engine has a lower carbon deposit. There may be less clean deposition when burning D95Pn5 cleaner in an environment with higher oxygen concentrations. But as figure 2 illustrates, test fuel D95Pn5 displayed less deposition.

### 3.3. Sound Emission Analysis

Although diesel fuel yielded the most favorable outcomes in terms of noise emissions, the use of alcohol/diesel blends particularly pentanol based blends, exhibited minimal differences in comparison with diesel fuel performance. This similarity is likely due to the comparable properties of high-carbon-chain alcohols and petroleum-based fuels. The high cetane number of pentanol reduces the ignition delay period, thereby lowering the cylinder pressure rise rate, and consequently, combustion noise (Solangi et al., 2024). Figures 3 and 4 display the sound levels recorded at the front and left locations of the test bed, alongside their mean values, for diesel fuel (DF) and the D95Bu5and D95Pn5 blends. Various factors contributed to the decreased noise levels of the blends, including the heating value of the fuel, which significantly affects cylinder pressure dynamics (Morgul, 2021).

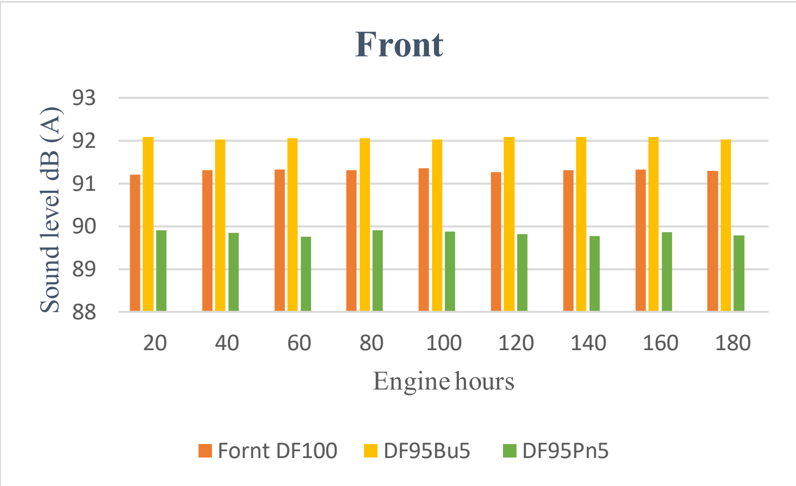


**Figure 3: Front Position of Sound Level for Test Fuels**

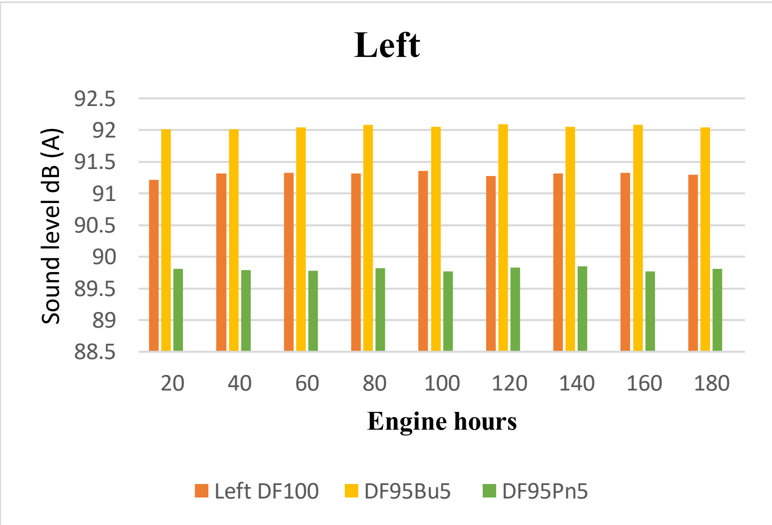


**Figure 4: Left Position of Sound Level for Test Fuels**

The duration of ignition delay is a critical factor that significantly influences overall combustion behavior. A gasoline's cetane rating serves as a barometer for how well it ignites. As a result, it affects ignition delay; a higher number indicates an earlier injection timing or a shorter ignition delay (Dandu & Nanthagopal, 2021). If the ignition delay is extended, typically because of the fuel's lower cetane number, a greater quantity of diesel is injected prior to ignition. Consequently, the rapid increase in combustion pressure produces louder noise, attributed to the sudden explosion of a larger fuel mass. The engine noise increases as greater mass of fuel undergoes rapid combustion, leading to faster rate of pressure rise within the cylinder. On the other hand, blend fuels' higher oxygen content increases combustion efficiency, which could lower noise levels. Consequently, D95Bu5 and D95Pn5 generated the least amount of noise in comparison to diesel fuel.The diesel engine using the D95Pn5 fuel blend has less copper wear, as seen in Figure 4. The highest concentration of copper is found in the binary D95Bu5 and DF combination. However, due to its extremely low or negligible concentrations, the computer considered the binary mixture D95Pn5 to be approximately non-detectable.

## 4. Conclusions

Through experiments, this study investigated the effects of mix fuels DF100, D95Bu5, and D95Pn5 on head surface deposits and engine wear. The results of the experiment could lead to the following deductions:

When it was fueled with D95Bu5, the engine head showed dry deposits as opposed to greasy or oily deposits when it was running on DF100 and D95Bu5.Following testing, the SEM analysis revealed that the D95Pn5 blend had substantially fewer engine head surface deposits than the D95Bu5 blend. The deposition caused the carbon layer to thicken unevenly. More precisely, an excessively wet exhaust valve was the result of using D95Bu5. This may be explained by the fact that the injected fuel would not dry when it struck the valve surface wall, causing the D95Bu5 deposits to become wet and brittle. examination of the debris and wear on the engine. It was discovered that D95Bu5 had a higher deposit formation than D95Pn5 and DF100.

Binary blend D95Pn5 had the lowest sound level in the engine noise emission test when compared to DF. However, the inclusion of n-pentanol as a ternary blend in D95Pn5 resulted in enhanced engine performance. This could be because of how their individual fuel characteristics affect reduced ignition delay and improved combustion efficiency because of the blends' higher oxygen content. Blends of diesel, waste cooking oil, and n-pentanol may be a good alternative to compression ignition engines in terms of noise emissions. Sound level tests, however, revealed more noise when the engine was running on the D95Bu5 blend as opposed to DF fuel.

**Authors Contribution**

Faheem Ahmed Solangi: Project supervision, writing original draft, revision and finalizing draft.
Tarique Ahmed Memon: Reviewing and editing draft and methodology reviewing.
Abid Ali Khaskheli: Methodology reviewing, data collection and editing.
Haris Jawad Arain: Data collection, data analysis assistance and editing.

**Conflict of Interests/Disclosures**

The authors declared no potential conflicts of interest w.r.t. the research, authorship and/or publication of this article.

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