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Assessment of Pongamia Pinnata Methyl Ester and Additives Impact on Direct Injection Diesel Engines

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Abstract:

The increasing scarcity, cost, and environmental impact of traditional fossil fuels are highlighting the importance of alternative energy sources. This study explores the use of Pongamia Pinnata methyl ester, a non-edible and widely available biofuel, in a diesel engine. The experiment evaluates the engine's performance and emission characteristics using various mixtures of Pongamia Pinnata methyl ester, 2-EHN, ethanol, and regular diesel. These blends, comprising 20%, 30%, and 100% biofuel by mass, were tested under different load conditions. The results indicate an improvement in both performance and emission parameters compared to standard mineral diesel. Notably, blends such as B20 A1(5) A2(5) D70, B20 A1(10) D70, and B20 A2(10) D70 showed superior brake thermal efficiency and indicated mean effective pressure under certain loads, with brake specific fuel consumption being equal or better than that of pure diesel. Additionally, the emission analysis revealed lower levels of carbon dioxide, carbon monoxide, and nitric oxide compared to emissions from pure diesel.

***Keywords*- Pongamia pinnata methyl ester, Transesterification, Engine performance & emission, A1- 2Ethylhexyle Nitrate, A2-Ethanol, B-Bio diesel, D-Pure diesel.**

1. INTRODUCTION

The urgent need to address environmental pollution and the diminishing reserves of fossil fuels has propelled researchers and engineers to focus on renewable alternatives to traditional energy sources. Extensive research has particularly targeted diesel engines, exploring not only advancements in engine design but also the viability of alternative fuels [1-4]. It has been widely recognized that biodiesel emerges as a promising substitute for conventional diesel fuel. Currently, the production of biodiesel primarily relies on oil crops such as rapeseed and sunflower. A comparative analysis of various fuel properties against pure diesel is detailed in Table 1. The process of transesterification, also known as alcoholysis, involves replacing one alcohol group in an ester compound with another alcohol. This reaction, akin to hydrolysis, can be represented by the equation RCOOR' + R"OH → RCOOR" + R'OH, facilitating the production of biodiesel from vegetable oils and alcohols. In the process of producing biodiesel, triglycerides undergo transesterification easily when exposed to an alkaline catalyst, conducted at atmospheric pressure and temperatures ranging between 600 to 700 degrees [references 4-5]. The automotive industry plays a major role in the emission of carbon dioxide, a key greenhouse gas contributing significantly to environmental concerns [6]. In the process of producing biodiesel, triglycerides undergo transesterification easily when exposed to an alkaline catalyst, conducted at atmospheric pressure and temperatures ranging between 600 to 700 degrees [references 4-5]. The automotive industry plays a major role in the emission of carbon dioxide, a key greenhouse gas contributing significantly to environmental concerns [6].

2. MATERIALS AND METHODS

Prior to initiating the performance and emission experiments involving various blends, the properties of Pongamia Pinnata, its methyl ester, and diesel were systematically documented in table (1) format for reference [13-15]. This preparatory step ensures a comprehensive understanding of the baseline characteristics of each fuel type involved in the study.

Table I: Properties of Pongamia Pinnata, Pongamia Pinnata Methyl Ester, and Diesel

Properties	Unit	Pongamiapinnata	Pongamiapinnata methylester	Diesel
Density@ 15^0 C	gm/cc	0.9358	0.797	0.850
Viscosity@ 40^0 C	cm /s ^{2}	38.8	7.0	2.6
Flash Point	^0C	212.0	97.8	70.0
Cloud Point	^0C	2.0	-7	-16
Pour Point	^0C	-4	-6	-20
Water Content	%	<0.05	0.03	0.02
Acid Value	mg of KOH/gm	16.8	0.42	0.35
Calorific Value	Kcal/kg	8742	3712	4290
Cetane Number		38.0	42.9	46

TABLE II 2.1 Diesel additive properties

Properties	Unit	2-EHN	Ethanol
Molecular weight	g/mol	175.23	46.06
Flash point	^0C	36	9
Freezing point	^0C	-45	-114
Boiling point	^0C	79.48	78.37
Auto ignition temperature	^0C	130	425
Density	gm/m^3	0.96	0.48

3. EXPERIMENTAL SETUP AND PROCEDURE

The experimental setup utilized a single-cylinder, four-stroke diesel engine connected to an eddy current dynamometer for testing. Water flow was measured using a Rota-meter for cooling purposes. Different loads (3 kg, 6 kg, 9 kg, and 12 kg) could be applied to the engine, allowing for a range of operational loads from 0% to 100% capacity (as depicted in Figure 1). Emissions of carbon monoxide (CO), nitric oxide (NO), and carbon dioxide (CO2) were measured in parts per million (ppm) using a five-gas analyzer installed at the exhaust to determine emission characteristics [6-9] (illustrated in Figure 2). Fuel consumption for both biodiesel and

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diesel was accurately measured using a glass burette, alongside a stopwatch for calculating the brake specific fuel consumption (BSFC) [11-13]. The experiments commenced at a consistent speed of 1500 rpm, with fuel injection timing fixed at 23° before top dead center (BTDC) for both diesel and Pongamia Pinnata Methyl Ester (PPME) fuels. Tests were conducted with various fuel blends, including D100, B20 A1(5) A2(5) D70, B20 A1(10) D70, B20 A2(10) D70, B20 B80, and B100, under progressively increasing load conditions ranging from 0% to 100% and at a compression ratio of 17.5:1. Performance evaluation was carried out on the specified diesel engine using standard diesel, Pongamia Pinnata oil methyl ester, and additives (2-EHN, Ethanol), as well as their respective blends with diesel. This was facilitated by ENGINE SOFT software developed by Apex Innovations Pvt. Ltd. (referenced in Figure 1). Exhaust gas analysis was performed using a TESTO 350 gas analyzer to calculate the emissions (referenced in Figure 2) [8-12].

Figure of experimental setup

Fig.1 Experimental setup

Fig.2 Gas analyser

4. RESULTS

4.1 Performance analysis

The experimental results, as illustrated in Figures 3 and 4, indicate that the brake thermal efficiency of the blend B20 A1(5) A2(5) D70 slightly surpassed that of pure diesel, suggesting a modest improvement in engine efficiency with this specific blend. Furthermore, the brake specific fuel consumption (BSFC) for blends containing Pongamia Pinnata biodiesel and additives was initially lower than that of pure diesel, aligning closely with diesel's consumption rates at higher load conditions [3-6]. The indicated mean effective pressure (IMEP) for all blends remained comparable to that of pure diesel, with the blend B20 A1(5) A2(5) D70 showing only a slight deviation from pure diesel at full load, demonstrating the potential for biodiesel blends to match or exceed diesel engine performance under varying operational conditions [6-11].

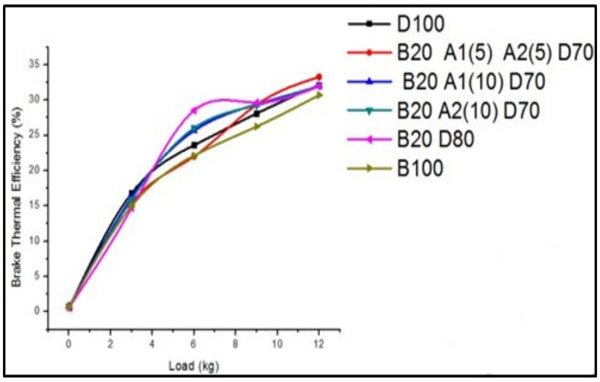

Fig3. bte vs. Load

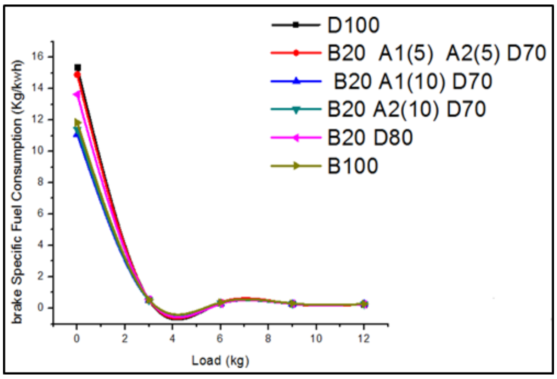

Fig4. bsfc vs. Load

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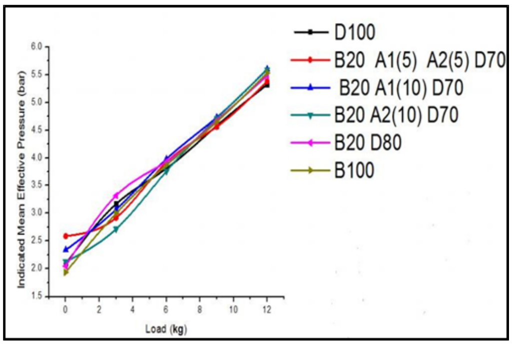

Fig5. imep vs. Load

4.2 Emission analysis

Utilizing biodiesel and additives results in a reduction of major exhaust pollutants, including CO2 (as shown in Figure 6) and CO (depicted in Figure 7). However, emissions of NO (illustrated in Figure 8) are marginally higher for the blend B20 A1(5) A2(5) D70
and other similar mixtures compared to D100. This indicates that while biodiesel blends effectively lower certain emissions, they slightly increase nitrogen oxide levels [10-15].

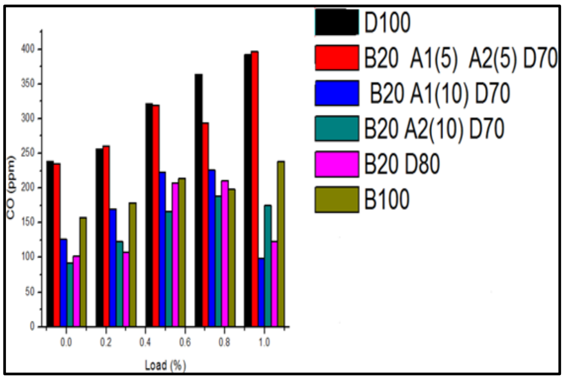

Fig6. CO vs. Load

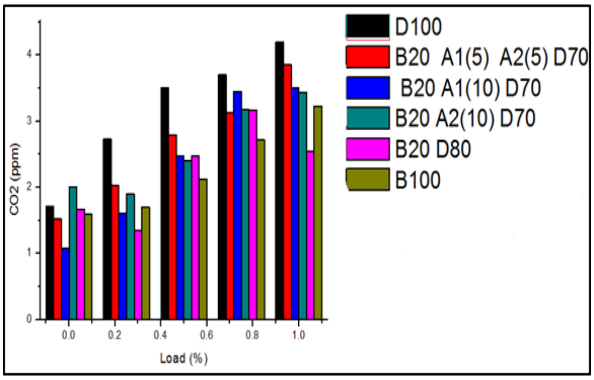

Fig7. CO2 vs. Load

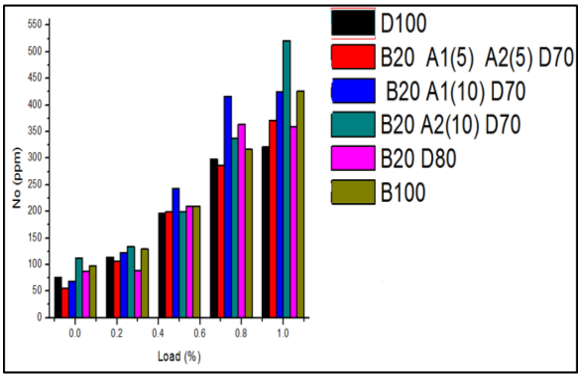

Fig8. NO vs. Load

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5. CONCLUSION

The study's findings, illustrated in Figure 3, reveal that the brake thermal efficiency of the engine was slightly higher when using the blend B20 A1(5) A2(5) D70 compared to pure diesel fuel. This indicates that incorporating Pongamia Pinnata methyl ester and additives can lead to more efficient fuel usage in diesel engines.

- Pongamia Pinnata methyl ester, along with diesel additives such as 2-EHN and Ethanol, shows promise as an alternative fuel for Direct Injection diesel engines, requiring no modifications to the engine.
- The brake thermal efficiency, as depicted in Figure 3, exhibited a slight improvement over that of pure diesel, with the blend B20 A1(5) A2(5) D70 achieving superior efficiency relative to standard diesel fuel.
- At the outset, brake specific fuel consumption (BSFC) for blends of Pongamia Pinnata biodiesel and additives is less than that of diesel, but as the load increases, it approaches the levels of pure diesel under full load conditions (as shown in Figure 4). Regarding indicated mean effective pressure (IMEP), it remains comparable to that of pure diesel across all blend conditions, with the blend B20 A1(5) A2(5) D70 showing only a slight variation from D100 when operating at full load.
- The utilization of biodiesel and additives significantly lowers the emissions of key pollutants like CO2 (shown in Figure 6) and CO (indicated in Figure 7). However, emissions of NO (referenced in Figure 8) exhibit a minor increase for the blend B20 A1(5) A2(5) D70, as well as for other mixtures compared to pure D100 diesel.
- Based on the experimental data regarding both performance and emissions, it can be inferred that the blend B20 A1(5) A2(5) D70 has the potential to replace diesel in diesel engines, offering improved performance.

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