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Performance and Emission analysis of Diesel Engine using Delonix Regia Biodiesel with Pentanol

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Abstract—*With the world moving towards new technological height every day, the automobile and fuel sector has also evolved considerably. Many researchers have shown a keen interest in search of alternative fuels, which are not only cleaner and greener but are also more economical and renewable. Biodiesel is renewable, less toxic, and biodegradable fuel and its combustion characteristics are comparable to petroleum diesel fuel, thus making it a promising fuel of the future. In this study, the interest is brought upon the Delonix Regia (Gulmohar) seed oil derived Biodiesel along with the addition of Pentanol-1 as an additive. The biodiesel is obtained from the delonix regia seed oil through trans-esterification. The fuel blends are prepared by adding biodiesel (10% and 20% by volume) along with Pentanol-1 (5% by volume) with diesel as base fuel. These blends along with biodiesel (100% by volume) and pure diesel are tested on Kirloskar TV1 type, four stroke, single cylinder, water-cooled diesel engine, one by one, to evaluate the performance and emission characteristic. The engine is tested at five different engine loads (0, 1.3, 2.6, 3.9 & 5.2 kW) with constant engine speed (1500 rpm). The use of pentanol-1 is restricted to 5% by volume for its benefits of decreased exhaust gas temperature, CO and NOx emissions when compared to use with a higher percentage of pentanol-1 blends. The study revealed that biodiesel and their blends could be used as an alternative fuel without any engine modification. Among all, B10+P5+D85 blend has found to be most promising fuel as it has lower specific fuel consumption, lower exhaust gas temperature, lower HC and CO_x emission when compared to diesel fuel and other blends.*

Keywords: *Delonix Regia (Gulmohar) seed oil, Biodiesel, Pentanol, performance, emission, diesel engine.*

1. INTRODUCTION

There has been high demand for petroleum based fossil fuels in the recent past due to increased automobiles and industries leading to faster depletion of reserved fossil fuels. Further, high dependency on fossil fuels resulted in increased environmental hazards, worsening Air Quality Index, global warming to name a few. This has adversely affected on human health and on ecosystem. Hence, it is necessary to find alternative sources of energies, which are not only cleaner and greener but are also more economical and renewable. Biodiesel is renewable, less toxic, and biodegradable fuel and its combustion characteristics are comparable to petroleum diesel fuel, thus making it a promising fuel of the future[1].

In this study, the interest is brought upon the Delonix Regia (Gulmohar) seed oil derived Biodiesel along with the addition of Pentanol-1 as an additive. The raw Delonix regia oil is extracted from oil seeds by crushing and other methods. The properties of raw delonix are closer to diesel fuel except its kinematic viscosity. The kinematic viscosity of raw oil is reduced by trans-esterification process to convert into delonix regia oil into desired biodiesel. In the last two decades, many researchers have studied about biodiesel fuels produce no sulphur dioxide and less aromatic hydrocarbon emissions. They are renewable, less toxic, and biodegradable and their combustion characteristics are comparable with petroleum diesel fuels. In addition, the biodiesel properties are similar to that of petroleum diesel fuels and they can be used as sole fuel or blended with diesel in diesel engines without any modification. Various researchers have conducted experiments to study the performance and emission characteristics of diesel engine when delonix oils, blends of delonix seed oil and its derivatives and it has been found to be economical and competitive compared to diesel fuel. Edward Ntui Okey et al. have investigated that diesel engine running with oil and diesel blends produces a closer performance and emissions characteristics to diesel for lower blend concentration of delonix oil [2]. Nadir YILMAZ et al. studied the "Emission characteristics of a diesel engine fueled with Diesel-1-pentanol blends" to evaluate the exhaust emission of 1-pentanol blends [3] . In their study, it was found that D95Pen5 with 5% of pentanol is better

alternative fuel for diesel engine as it decreases exhaust gas temperature, CO and NOx emissions at the expense of increasing HC emissions when compared to higher percentage of Pentanol. From there conclusion, it is decided to experiment the engine with use of pentanol restricted to 5% by volume for desirable outcome.

Table 1. Properties of Diesel, Pentanol and Delonix Regia seed biodiesel

Parameters	Dies el	Pentanol	Biodiese l
Kinematic viscosity at 40°C (Cst)	2.6	2.83	4.42
Density at 15°C (g/cc)	0.80 72	0.814	0.8822
Gross Calorific value (kJ/kg)	4460 0	35	42.425
Flash Point (°C)	74	49	159
Fire Point (°C)	84	300	171
Pour Point (°C)	-23	-	-6
Specific gravity at 15°C	0.83 5	-	0.8821

2. MATERIALS AND METHODS

2.1 Preparation of biodiesel

Preparation of biodiesel from Delonix Regia seed oil by transesterification, it is a process of using methanol (CH_3OH) in the presence of catalyst Potassium hydroxide (KOH) to chemically brake the molecule of raw oil into ester and glycerol. This process is a reaction of the oil with an alcohol to remove the glycerin, a byproduct of biodiesel production.

2.2 Procedure for trans-esterification

1000 ml of Delonix Regia seed oil is taken in a container. 18 grams of Potassium hydroxide alkaline catalyst (KOH) is weighed. 250 ml of methanol is taken is beaker. KOH is mixed with the alcohol and it is stirred until they are properly dissolved. Delonix Regia seed oil is taken in a container and is stirred with a mechanical stirrer and simultaneously heated with the help of a heating coil. The speed of the stirrer should be minimum and when the temperature of the raw Delonix Regia seed oil reaches 60°C the KOH-alcohol solution is poured into the raw oil container and the container is closed with an air tight seal. Now, the solution is stirred at high speeds (720 rpm). Care should be taken that the temperature does not exceed 60°C as methanol evaporates at temperatures higher than 60°C. Also, the KOH-alcohol solution is mixed with the raw oil only at 60 °C because heat is generated when KOH and alcohol are mixed together and the temperature of the raw oil should be more than this when mixing is done if the reactions have to take place properly. After stirring the oil-KOH-alcohol solution at 60 °C for two hour the solution is transferred to a glass container. Now separation takes place and biodiesel gets collected in the upper portion of the glass container whereas glycerin gets collected in the bottom portion. This glycerin is removed from the container. Then the biodiesel is washed with water. Again glycerin gets separated from the biodiesel and is removed. The biodiesel is washed with water repeatedly until no glycerin is there in the biodiesel. Now this biodiesel is heated to 100°C to vaporize the water content in it. The resulting product is the biodiesel which is ready for use.

(a) (b)

Figure 1. (a) Delonix Regia (DR) seed oil
(b) Separation of Biodiesel from DR seed oil

3. EXPERIMENTAL SET-UP

The experiments were performed on Kirloskar TV1 type, four stroke, single cylinder, water-cooled diesel engine connected to eddy current dynamometer (see Figure 2). The technical specification of test engine are brought in Table 2. The exhaust emissions were measured with an AVL DI GAS 444 N (five gas analyser) details for which is enlisted in Table 2. The parameter like absorption (K value) and opacity were measured with AVL 437C smoke meter.

Figure 2. Engine test rig

Table 2. Technical specification of the test engine

Engine Make	Kirloskar
Model	TV1
Type	Direct Injection
Rated Speed	1500RPM
Rated Power	5.2kW

Bore*Stroke Length(mm)	87.50*110
Cubic Capacity (cm^3)	661.45
Connecting rod length(mm)	234
Compression Ratio	17.50

The type of Eddy current dynamometer is of Techno Mech (TMEC-10) make, maximum 7.5kW with revolution ranging from 1500-6000rpm attached with engine output shaft to vary load. The burette is connected to engine through three-way cock to measure fuel consumption

Table 2. Technical specification of AVL DI GAS 444 N gas analyser

Measurement data	Resolution
CO – 0-15% Vol	0.0001% Vol
HC- 0-20000 ppm Vol	1 ppm/10ppm
CO2 – 0-20% Vol	0.1% Vol
O2 – 0-25% Vol	0.01% Vol
NOx 0-6000 ppm Vol	1ppm Vol
Cubic Capacity (cm^3)	661.45

4. RESULT AND DISCUSSION

An experimental investigation is carried out by testing blends B10+P5+D85 (DR seed Biodiesel 10% by vol. + Pentanol 5% by vol. + Diesel 85% by vol.), B20+P5+D75, B100 & pure diesel on Kirloskar TV1 diesel engine. The results obtained from the above blends is compared for performance analysis and emission analysis by means of line graph and cluster columns. The following gives the variation of performance parameters like indicated power, brake power, brake mean effective pressure, specific fuel combustion and exhaust gas temperature for the various discussed blends under different loading conditions followed by emission analysis like CO emission, NO_x Emission and HC emission.

4.1 Indicated Power

The line graph between indicated power and load with increment of 25 % engine load capacity starting from no load to full load condition (see Figure 3). The plot reveals that upto 50 % load condition there is marginal difference in Indicated Power of B10+P5+D85, B20+P5+D75, B100 & Pure Diesel and with further increase in load the lines tends to merge indicating almost equal performance at full load condition.

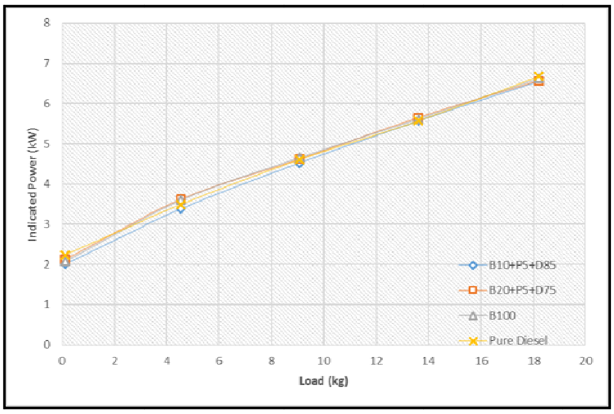

Figure 3. Variation of indicated power with load

4.2 Brake Power

Figure 4. shows the line graph between Brake Power and load with increment similar as above. The comparison of Brake Power lines are almost coinciding for various blends (B10+P5, B20+P5, B100 & Pure Diesel) tested indicating negligible effect in delivering the Brake Power at various load condition

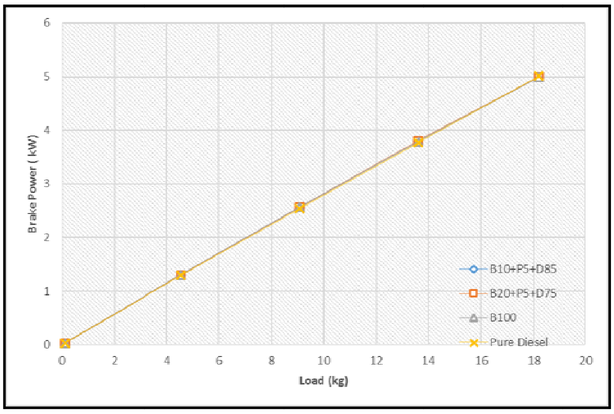

Figure 4. Variation of brake power with load

4.3 Brake Mean Effective Pressure

Figure 5. shows the line graph between Brake Mean Effective Pressure and load with increment in load as above. The comparison of Brake Power lines are almost coinciding for various blends (B10+P5, B20+P5, B100 & Pure Diesel) tested indicating negligible effect in delivering the Brake Mean Effective Pressure at various load condition.

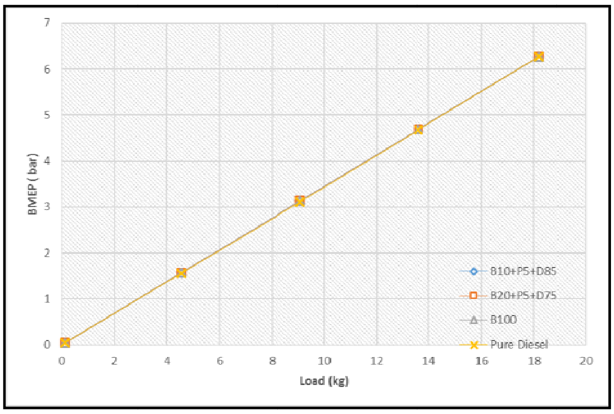

Figure 5. Variation of brake mean effective pressure with load

4.4 Specific fuel consumption

Figure 6. shows the graph between specific fuel consumption and load with increment in load. The comparison of specific fuel consumption lines are separated for various blends (B10+P5, B20+P5, B100 & Pure Diesel). For B100, the specific fuel consumption found to be more and B10+P5+D85 found to be least when compared to other blends. All blends has shown decrease in specific fuel consumption with increasing in load.

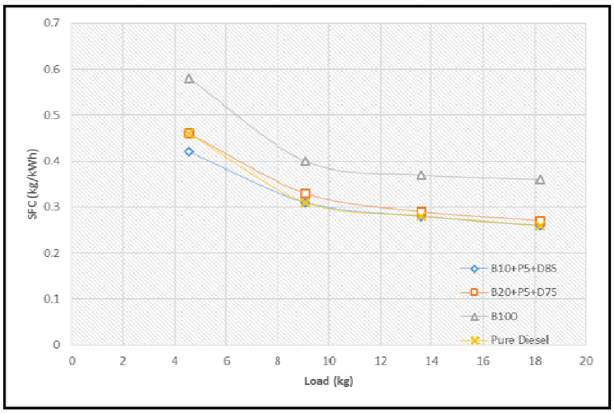

Figure 6. Variation of specific fuel consumption with load

4.5 Brake thermal efficiency

Figure 7. shows the plot between variation of Brake Thermal Efficiency and load. From graph, it can be seen that the Brake Thermal Efficiency is found to better for B10+P5+D85 blend when compared to B100 and almost same as that of pure diesel.

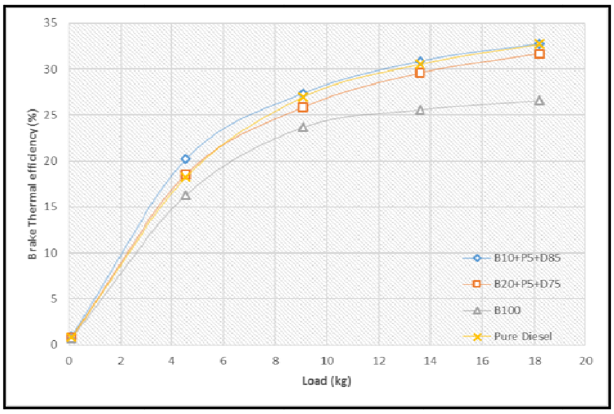

Figure 7. Variation of brake thermal efficiency with load

4.6 Exhaust gas temperature

Figure 8. shows the variation of exhaust gas temperature with respect to load. Among all B10+P5+D85 is showing less exhaust gas temperature which indicates the positive impact of pentanol when restricted to 5% by volume. These results are similar to Nadir Yilmaz et al. [3] in literature.

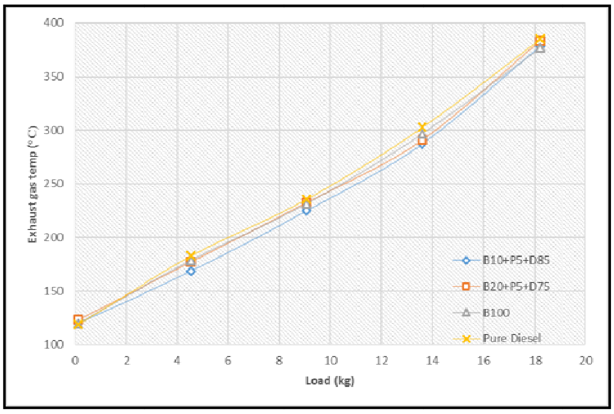

Figure 8. Variation of exhaust gas temperature with load

4.7 Cylinder pressure (bar) vs crank angle at 100% load

Figure 9. shows the line graph between cylinder pressure and crank angle. The crank angle for test engine is considered from -50° to +50°. The points were plotted and smooth curve is passed through the points. Again, B10+P5+D85 blend is showing enhanced cylinder pressure which means better compression and combustion. Also the cylinder pressure of B20+P5+D75 blend and B100 has also shown better results when compared to pure diesel.

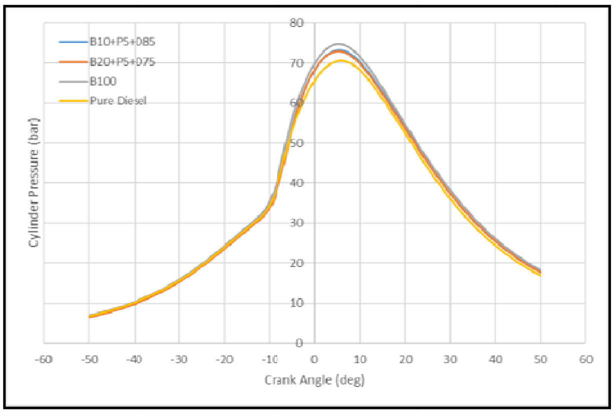

Figure 9. Variation of cylinder pressure (bar) vs crank angle at 100% load

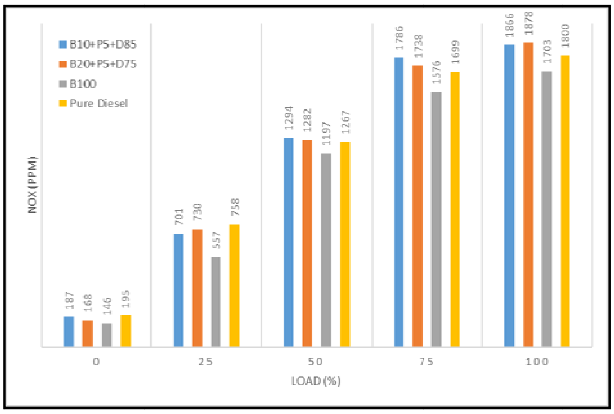

Figure 11. Variation of NOx emission vs load

4.8 CO emission

The variation of CO emission as a function of engine load for various blends are depicted in Figure 10. Scarcity of oxygen concentration inside the cylinder and overly lean or rich mixtures leads to formation of higher CO formation. As pentanol has higher latent heat of vaporization it absorbs more heat from the combustion chamber resulting in higher CO emission.

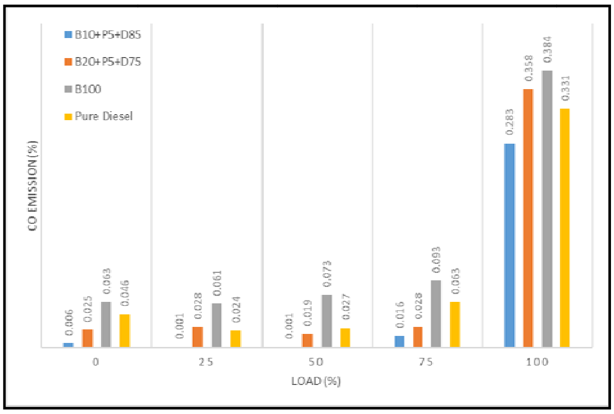

Figure 10. Variation of CO emission (%) with load

4.9 NO_x emission

Figure 11. shows the variation of NO_x emission with load of engine. As it can be seen from graph that NOx emission increases with increase in load resulting in higher combustion temperature and higher NO_x emission. At no load condition, the NO_x emission were vey less. But as the load on engine increases the NO_x emission also increases. Except B100, almost all blends have shown rise in NO_x emission rate when compared to pure diesel.

4.9 HC emission

Figure 11. shows the variation of HC emission (ppm) with load of engine. As it can be seen from graph that HC emissions also increases with increase in load. HC emissions occurs due to incomplete combustion or slower oxidation reaction due to removal of heat from the cylinders and quenching of flame.

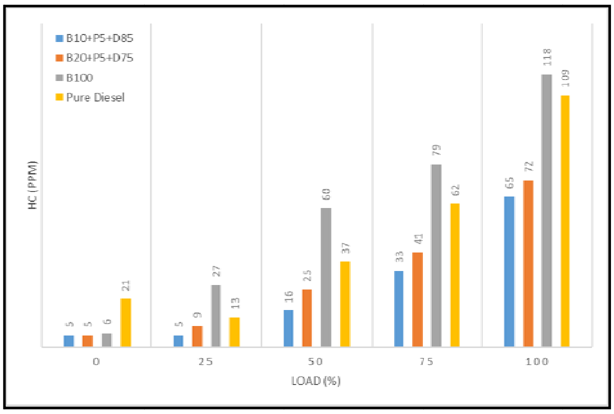

Figure 12. Variation of HC emission (PPM) with load

4.10 Smoke

Figure 13. shows the variation of opacity with load of engine. As it can be seen from graph that smoke emission increases with increase in load. At no load condition, the NO_x emission were vey less. Almost for all blends the smoke opacity has not been better when compared to diesel.

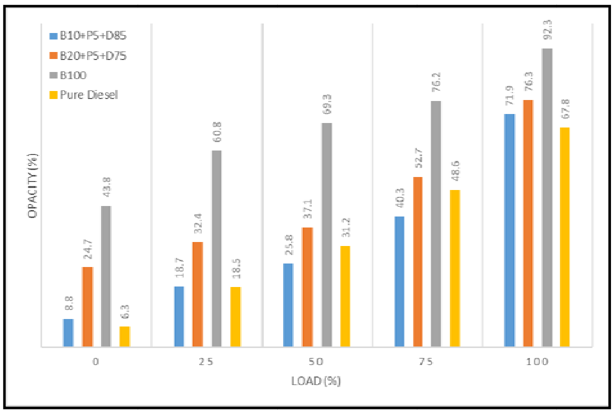

Figure 13. Variation of Opacity (%) with load

5. CONCLUSION

In this paper, effect of combination of pentanol, Delonix Regia seed derived biodiesel and pure diesel were examined for performance and emission characteristics without any engine modification and following conclusions are brought out:

- All blends were tested safely on the engine test rig without any engine modification.
- Performance parameters and emission parameters were calculated and plotted on graph and discussed.
- It is experimentally verified that the blend B10+P5+D85 outperforms when compared to others as it has
  - lower specific fuel consumption
  - lower exhaust gas temperature
  - lower HC emission
  - lower CO emission
  - Better cylinder pressure
  - Better brake thermal efficiency

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