

# An Experimental Investigation of Pongamia based Biodiesel in DI Diesel engine using Air Preheater

Gnanamoorthi Vengadesan\*, Barani Chandar Kathavarayan

Department of Mechanical Engineering, University College of Engineering, Villupuram, Tamilnadu, India.

\*Corresponding author: E-Mail: cvgnana@gmail.com

## ABSTRACT

The aim of this study is to identify the effect of inlet air preheating for Pongamia oil blend with diesel on CI engine. Pongam tree is an underutilized which is grown in many parts of India. The pongamia pinnata is drought resistance, semi deciduous, nitrogen fixing leguminous tree contaminated with acids depending upon the water content available in the seed. This works effort to improve the performance of diesel engine by using pongamia oil diesel blend (P10, P20, and P30) with aid of preheated inlet air at 90°C. The performance parameters considered for comparing are brake power, brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature and the emission parameters are CO, HC, Nox and smoke emission of the engine. The engine offers same brake thermal efficiency, but in the case of brake specific fuel consumption at high load it is slightly increase for pongamia oil blend compared with diesel when it is powered by heated inlet air. The CO and Nox emission increase with the increase in the fuel inlet air and the HC emission is identical to the non-heated inlet air.

**KEY WORDS:** Alternative fuel, Compression ignition engine, neat Pongamia oil, preheating.

## 1. INTRODUCTION

Due to limited availability of fossil fuels, elevated crude oil prices and the increasing concerns for environment problems leads to many researcher to focus alternative resources. The first attempt to replace the diesel is peanut oil used by Rudolf Diesel in the year of 1910 for his newly developed diesel engine. In some case the straight biofuel cannot be used straightaway because of its physical properties. Some of the non-edible oils such as mahua, neem (*Azadiracta indica*), Pongamia (*Pongamia pinnata*), jatropha (*Jatropha curcas*), castor, rice bran, linseed, etc. can be used in diesel engines after some chemical treatment. The property like viscosity and volatility of the oil which is derived from seeds or plants is higher, and these can be brought down by a process known as trans esterification and emulsification. However, trans esterification is a more expensive, time ingests and tangled process. One simple technique to use heavy viscosity oil in CI engine is air preheating. It needs fewer modifications in the engine. Pongamia is one such forest-based tree- non-edible oil with a potential of 135,000 million tones. Hence it finds attraction to utilize as alternative fuel for diesel in CI engines. The physical and chemical properties of pongamia oil like calorific value, density, volatility are very closer to conventional diesel, moreover, the pongamia oil has oxygen in it which can boost the combustion process. Despite that, the outrageous viscosity and indigent volatility of pongamia oil are difficult to handle by the conventional fuel injection system. Inlet air preheating results reduction in viscosity of oil with better performance and lower emissions in a diesel engine fuelled with neat Pongamia oil. In this work, effect of air preheating using Pongamia oil diesel blend as fuel in a diesel engine is investigated. Experiments were carried out at the constant rpm engine with under no load to full load conditions. A discrete heater arrangement is made to preheat the inlet at 90°C. The performance and emissions parameters are analyzed and compared with neat diesel.

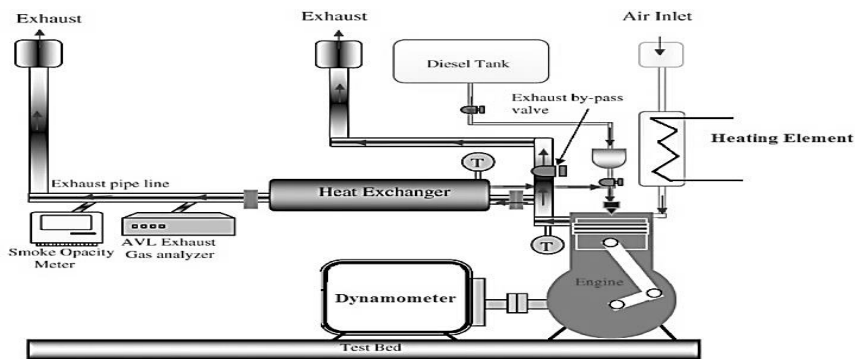
## 2. EXPERIMENTAL SETUP AND EXPERIMENTAL PROCEDURE

The schematic diagram of the experimental setup is illustrated in Fig.1. The test engine specifications are given in Table.1.

The engine used for this experiment was a computerized single cylinder four stroke constant RPM diesel engine modified to operate in dual fuel mode. The engine was coupled to an eddy current dynamometer, which provides load on the engine. Engine soft software is used to determine the temperature, pressure and heat released or transferred at each stroke or crank angle. Exhaust gas analyzer and smoke meter is used for measuring Nox, CO, HC, CO<sub>2</sub>, O<sub>2</sub> and smoke respectively.

**Table.1. Specification of the test engine**

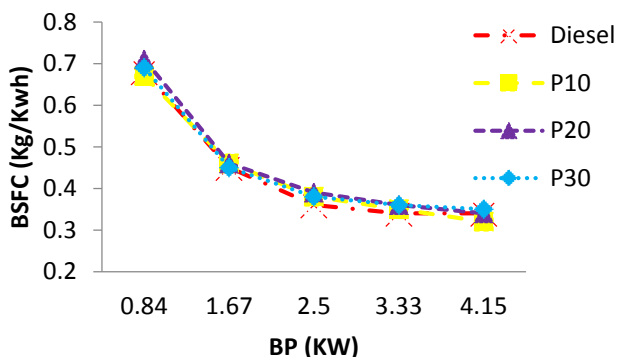
<b>Make/model</b>	Kirloskar TV1
<b>Engine type</b>	Single cylinder, four stroke, CI, water cooled, naturally aspirated, direct injection, constant speed
<b>Brake power, KW</b>	5.2
<b>Rated sped, rpm</b>	1500
<b>Displacement volume, cm<sup>3</sup></b>	661
<b>Injection pressure, bar</b>	200
<b>Injection timing, °CA bTDC</b>	23
<b>Compression ratio</b>	17.5



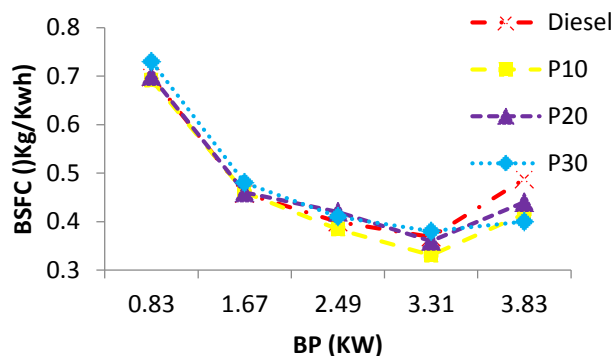
**Fig.1. Engine setup**

The properties of the diesel fuel and neat Pongamia oil are cited in as expectedly, the specific gravity and kinematic viscosity of the Pongamia oil gradually decrease with the preheating temperature.

**3. RESULTS AND DISCUSSION**



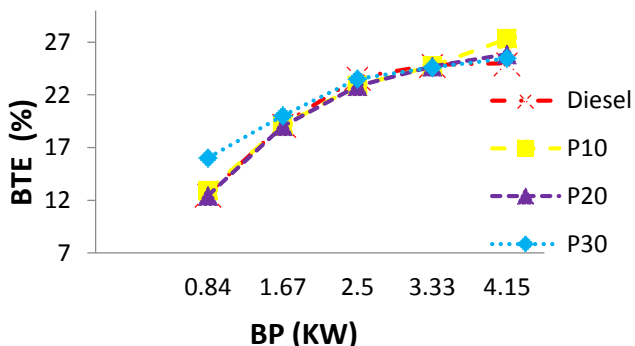
**Fig.2. Variation of BSFC with Brake Power without heating**



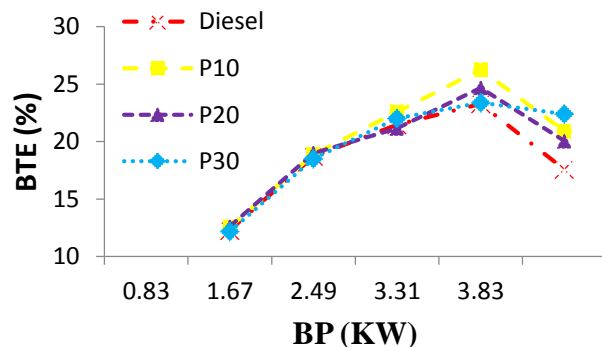
**Fig.3. Variation of BSFC with Brake Power with heating**

Fig.2 shows the variation of BSFC with Brake Power for diesel with different proportions of biodiesel. The BSFC increases initially for all fuels and then decreases rapidly up to the part load with respect to increase in brake power and load. This is due to increased frictional and incomplete combustion losses at higher speeds (low loads), that increases specific fuel consumption. Initially, BSFC increases for blends when compared to diesel.

From Fig.3 shows the variation of BSFC with Brake Power with heating, the BSFC increases at the high load while heating the inlet air. This may be due to increased temperature of inlet air which increases the temperature of the combustion chamber. The combustion conditions become more favourable which results shortening ignition delay time which affects both chemical and physical reaction, this situation contributes to increase BSFC when compared to biodiesel without air preheating.



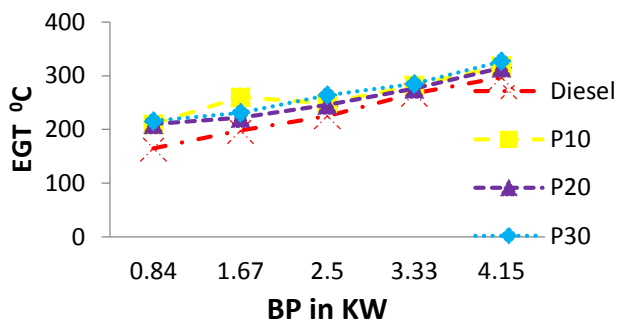
**Fig.4. Variation of BTE with Brake Power without heating**



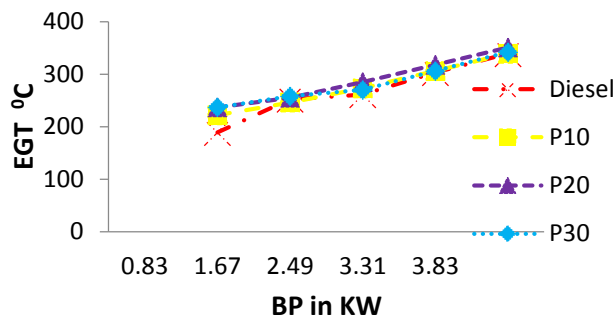
**Fig.5. Variation of BTE with Brake Power with heating**

Fig.4, shows the variation of BTE with Brake Power for diesel with different proportions of biodiesel. BTE increases with increase in brake power and load; this is due to reduction in BSFC will increase the brake thermal efficiency. At full load condition P10 has better efficiency than diesel which may be due to higher combustion efficiency of P10 due to the presence of oxygen in the fuel.

Fig.5, shows the variation of BTE with Brake Power with heating, BTE for inlet air preheated biodiesel is similar to that of the non-air preheated biodiesel. For the P10 blend the BTE is increased by 5.6%. This is due to the oxygen availability in the pongamia oil gives better fuel consumption delivering improved thermal efficiency. The decrease in BTE for higher blends may be due to the combined effect of its lower heating value and increase in fuel consumption.



**Fig.6. Variation of EGT with Brake Power without heating**

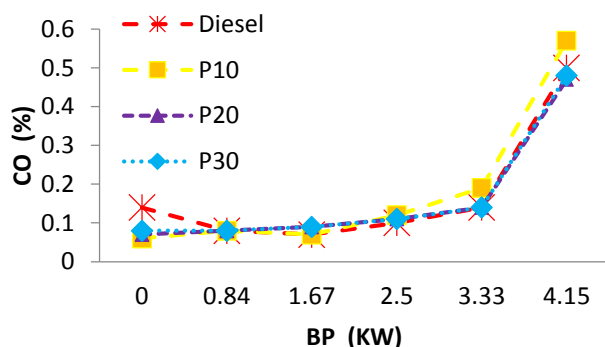


**Fig.7. Variation of EGT with Brake Power with heating**

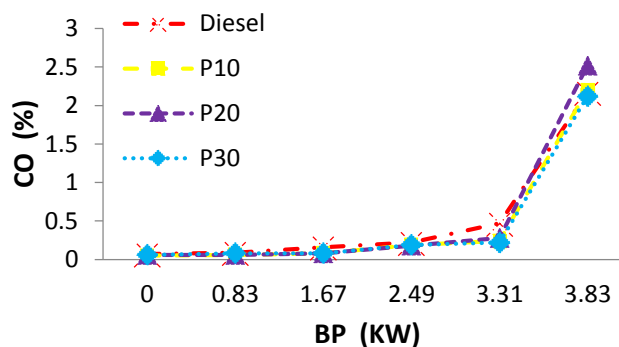
Fig.6, shows the variation of EGT with Brake Power for diesel with different proportions of biodiesel. Exhaust Gas Temperature increases with increase in brake power. This is due to increase in combustion chamber temperature with increase in brake power. EGT is more for various blends when compared with diesel. The biodiesel has more oxygen content than diesel, so the combustion chamber temperature will be higher than diesel. From Fig.6, P30 has high exhaust gas temperature than diesel and other blends.

Fig.7, shows the variation of EGT with Brake Power with heating. The EGT is increased in all the cases of biodiesel compared to that of diesel. The air preheating technique maintain the high combustion chamber temperature and also the availability of the oxygen helps to better combustion results higher EGT.

**Emission Characteristics:** Fig.8, shows the variation of CO with Brake Power for diesel with different proportions of biodiesel.



**Fig.8. Variation of CO with Brake Power without heating**

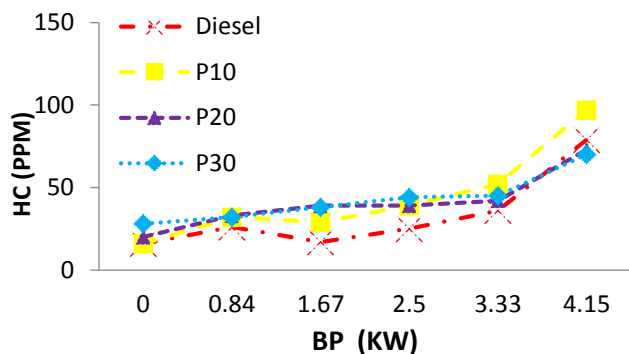


**Fig.9. Variation of CO with Brake Power with heating**

It is noted that the engine emits more CO for diesel as compared to Pongamia blends under all the load conditions. It is seen from Fig.8, that the Carbon monoxide concentration is reduced for P10, P20, and P30 than diesel due to the presence of more oxygen content in Pongamia blends.

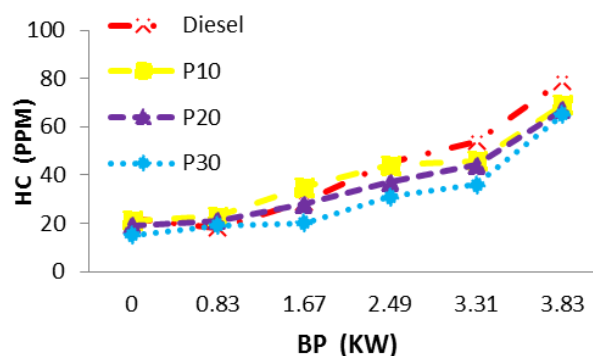
Fig.9, shows the variation of CO with Brake Power with heating, it is clear the CO emission is comparatively lower than the biodiesel without preheating. The CO, which arises mainly due to incomplete combustion, is a measure of combustion in efficiency. In general oxygen available in biodiesel is high and high inlet air temperature, at high temperature carbon easily combines with oxygen and reduces the CO emission.

Fig.10, shows the variation of HC with Brake Power for diesel with different proportions of biodiesel. It is interesting to note that the engine emits more HC for diesel as compared to Pongamia blends under all the load conditions. As the cetane number of ester based fuel is higher than diesel, it exhibits a shorter delay period and results in better combustion leading to low HC emission. Comparatively from Fig.11, the hydrocarbon emission is lower than the biodiesel without preheating. The high inlet air temperature reduces the viscosity and density of the fuel and induced better mixing with air results complete combustion.

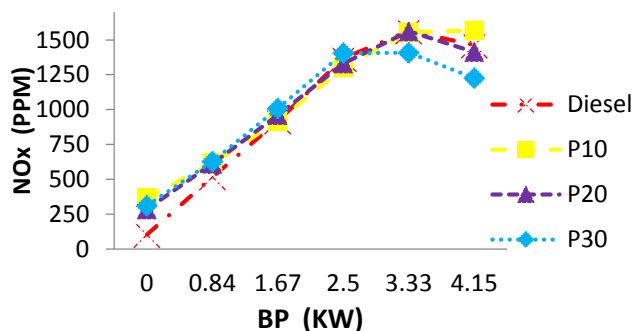


**Fig.10. Variation of HC with Brake Power without Heating**

It is seen from Fig.10, and 11, that the Hydro Carbon concentration is reduced for P10, P20, and P30 than diesel due to the presence of more oxygen content in Pongamia blends.

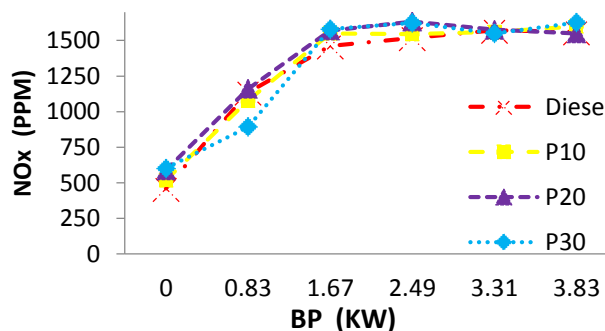


**Fig.11. Variation of HC with Brake Power with heating**



**Fig.12. Variation of NOx with Brake Power without heating**

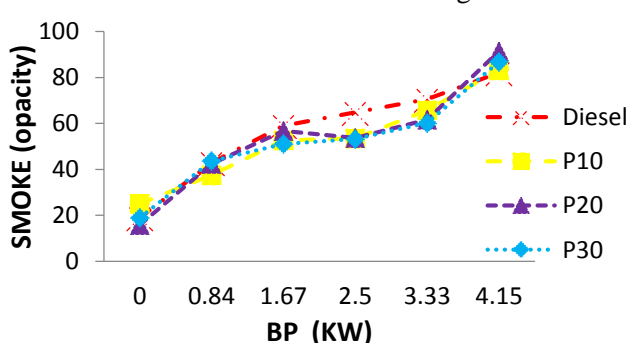
Fig.12, shows the variation of NOx with Brake Power for diesel with different proportions of biodiesel. Biodiesel has higher NOx emission due to higher cetane number which reduces the ignition delay. As a result of reduction in ignition delay, the duration of combustion increases which results in NOx formation. With increase in blend ratio there is an increase in NOx emissions.



**Fig.13. Variation of NOx with Brake Power with heating**

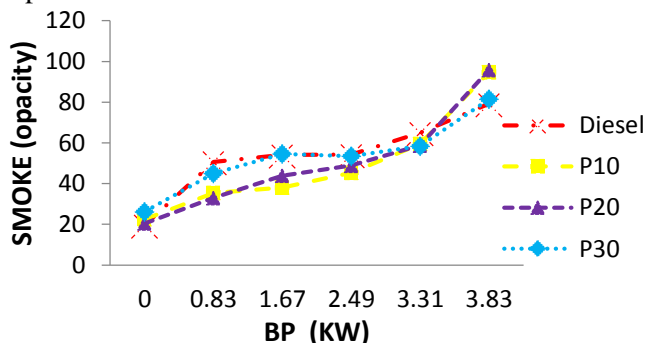
Fig.13, shows the variation of NOx with Brake Power with heating. The Nox emission is higher compared to that of biodiesel without heating. This may be due to the high combustion chamber temperature by the high inlet air temperature. During combustion, the nitrogen bound in the fuel is released as a free radical and ultimately forms free  $\text{N}_2$ , or NO.

Fig.14, shows the variation of Smoke with Brake Power for diesel with different proportions of biodiesel. The smoke increases with increase in engine load and brake power.



**Fig.14. Variation of Smoke with Brake Power without heating**

At peak load condition, the smoke formations are slightly increases for P10, P20 and P30 than diesel. Higher blend concentration gives higher smoke at even lower loads, and it was higher than that of mineral diesel but the increase was not as high. Higher smoke opacity may be due to poor atomization of the Pongamia oil. Bulky fuel molecules, higher viscosity of pongamia oil and low volatility results in poor atomization of fuel.



**Fig.15. Variation of Smoke with Brake Power with heating**

Fig.15, shows the variation of Smoke with Brake Power with heating. The smoke emission for the biodiesel with inlet air preheating is lower than that of biodiesel without heating. This may be due to the reduced viscosity of the biodiesel by the help of inlet air preheating and also the good mixture formation. In addition to that, for biodiesel

operation the smoke values reduced because of the atomic bounded oxygen which helps in better combustion, thus reducing smoke.

#### 4. CONCLUSION

The present study has dealt with the production of biodiesel from Pongamia oil, measurement of properties and performance evaluation on blends of biodiesel at various loads with inlet air preheated at 90°C. The following conclusions can be drawn that the fuel properties like density, flash point, viscosity and calorific value of P10 is very similar to diesel and therefore diesel may be well replaced by biodiesel in future. Thermal efficiency of the engine with pongamia oil blends are nearly 24–27%. The smoke density from exhaust gas of lower blends was almost similar to that of diesel fuel. The HC emissions from lower blends (P10 and P20) are lower than that of mineral diesel. The emissions of NOX from the blends are slightly higher than diesel at all load conditions.

These are the significant advantage over mineral diesel while using pongamia oil and their blends. Hence it can be concluded that the pongamia oil blends with diesel up to 10% would replace diesel for running the CI engine for lower emissions and improved performance.

#### REFERENCES

- Abbas MK, Davis IL, The composition of organic fraction of particulate emission of a diesel engine operated on pongamia oil, SAE 901563, 1990.
- Agarwal AK, Das LM, Biodiesel development and characterization for use as a fuel in compression ignition engines, J Eng Gas Turb Power, 123, 2001, 440–447.
- De Almeida SCA, Belchior CR, Nascimento MVG, Vieira LdSR, Fleury G, Performance of a diesel generator fuelled with palm oil, Fuel, 81 (16), 2002, 2097–2102.
- Dhinagar S, Nagalingam B, Experimental investigation on non-edible pongamia oil operation in a LHR diesel engine for improved performance, SAE 932846, 1993.
- Ghormade TK, Deshpande NV, Soybean oil as an alternative fuels for I.C. engines, In: Proceedings of recent trends in automotive fuels, Nagpur, India, 2002.
- Masjuki HH, Kalam MA, Maleque MA, Kubo A, Nonaka T, Performance, emissions and wear characteristics of an I.D.I diesel engine using coconut blended oil, J Automobile Eng., 3, 2001, 393–404.
- Rao P.V, Effect of properties of Pongamia methyl ester on combustion and NOx emissions of a diesel engine, Journal of Petroleum Technology and Alternative Fuels, 2 (5), 2011, 63-75.
- Shruthi H Heroor, and Rahul Bharadwaj S.D, Production of Bio-fuel from Pongamia and its Performance on Ci-engine, International Journal of Environmental Engineering and Management, 4 (6), 2013, 585-592.
- Venkatesan M, Vikram C.J, and Naveenchandran P, Performance and Emission Analysis of Pongamia Oil Methyl Ester with Diesel Blend, Middle-East Journal of Scientific Research, 12 (12), 2012, 1758-1765.
- Wang YD, Al-Shemmeri T, Eames P, McMullan J, Hewitt N, Huang Y, An experimental investigation of the performance and gaseous exhaust emissions of a diesel engine using blends of a pongamia oil, Appl Thermal Eng., 26, 2006, 1684–1691.