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Experimental Investigation of Pongamia oil as an Alternative Fuel for Diesel Engine

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Abstract - The world is facing the major problem of depletion of conventional fuels. The scarcity of oil reserves will make renewable energy resources more attractive. The most feasible way to meet this growing demand is by using alternative fuels. This paper deals with the production of biodiesel from Pongamia oil, the properties of raw and transesterified oil and performance study in diesel engine were conducted. Pongamia as biodiesel were tested for their performance in diesel engines. The biodiesel for various proportions like 5%, 10%, 15% and 20% and the effect on diesel engine performance is studied. The effect of use of biodiesel on engine power, fuel consumption and heat loss involved are collected and analyzed with that of conventional diesel.
Keywords : Biodiesel, Pongamia oil, Trans-esterification, IC Engine, Emission.

I. INTRODUCTION

In the present energy–environment emergencies, it got the key to recognize renewable. Vegetable oils exhibit an extremely better option to diesel oil, since they are renewable, biodegradable and clean blazing, having properties comparable to that of diesel. It has been found that the tree species like Pongamia Pinnata ('Honge' or 'Karanja') and Jatropha, which would be exceptionally suitable for oil extraction in our Indian conditions. Pongamia Pinnata is one of the woods based tree-borne non-palatable oil with a generation capability of 135,000 metric tons for every year in India. It is one of only a handful few nitrogen fixing trees (NFTs), which deliver seeds containing 30–40% oil. Different specialists have led examinations to contemplate the execution and discharge attributes of diesel motor when vegetable oils, mixes of vegetable oil and its subordinates are utilized as fuel and it has been observed to be conservative and aggressive contrasted with standard diesel. Biodiesel is a fuel got from vegetable oils by altering their atomic structure through a transesterification process. Transesterification includes a response in a triglyceride and liquor in vicinity of an impetus to deliver glycerol and ester.

Baste S.Vetal et al. [1] analyzed the properties of esterified karanja oil and its mixture with diesel fuel for various proportions. The engine tests are conducted and were found that the karanja oil blend up to 25% with the petrodiesel meets the standard. The blending of petro diesel up to 20% (by volume) with this oil can be used safely in a CI engine without any engine modification and aids in controlling air pollution.Gajendra Singh et al.[2] investigated the prospect of making of biodiesel from Karanja oil and seen that 950ml biodiesel is Produced from 1 liter of Karanja oil. The seeds of Karanja contain 70-75% oil. In this study the oil has been converted to biodiesel by Transesterification process and used it to diesel engine for performance evaluation. K.Nanthagobal et al. [3] conducted the combustion analysis on biodiesel as a substitute for diesel, proves that delay period decreases. Raghavendra Prasada S.A et al. [4] concluded that the blends of Karanja with 40% and 60% with diesel, the combination of both mixtures of fuel can replace the emission without sacrificing the power output and will be controlling the exact air pollution for the engine.

M.Prabhahar et al. [5] measured the performance characteristics like BSFC, BTE, and NOx, CO, HC emissions. The BSFC, BTE increased at pressure 220Bar.The emissions of CO and smoke reduced 33% and 25% respectively. Nagarhalli M.V et al. [6] performed the experiment with injection pressure is at 200 bar throughout. The emission characteristics of HC and NOx decreased by the mixture of B20 is 12.8% and 39%.The another mixture of B40 is 3%, 28% respectively. At full load condition, BSFC is gradually increased 7% on B20 and 1.9% on B40.H.K.Amarnath et al.[7] Analyzed the emission of diesel, Karanja, jatropha, and palm biodiesels where NOx is increased, whereas HC emission will be increased and HC emission will be reduced. The BTHE is increased at 7%, whereas compression ratio extended 14 to 18.

B.Baiju et al. [8] found that NOx emissions growth by 10–25% whilst fuelled with diesel–biodiesel gasoline blends in comparison to standard diesel fuel at part masses. At complete load, diesel emits more NOx than esters. Most of the important exhaust pollution such as CO, HC, and smoke are reduced with using biodiesel and the blends.

Avinash Kumar Agarwal et al. [9] investigated the performance parameters and emission characteristics of biodiesel with two different conditions. That is preheated blend and normal blend. At preheated oil blends the thermal efficiency will be extended nearly 30% and lower blends like K10, K20, K50 it was slightly improved the thermal efficiency from 24% to 27%. The comparative of both the conditions BSFC and BSEC will be improved for preheating blends. Dinesha P et al.[10] the most extreme brake warm effectiveness for B40 is observed to be 38.83% at110°C at 75% stacking taking after 37.87% at full load condition. 8.97% and 6.97% expansion in brake warm productivity are gotten over B20 mix at 75% and full load condition. Avinesh Kumar Agarwal et al. [11] reported fuel utilization and warm proficiency are moderately the second rate for all Karanja oil mixes contrasted with mineral diesel. HC outflows were lower for Karanja oil mixes than mineral diesel for the entire motor working extent overall mix fixations. CO and NO emanations were marginally higher for higher Karanja oil mixes. Smoke was lower for lower Karanja oil mixes contrasted with mineral diesel. S.K.Acharya et al. [12] determined that in contrast with Kusum oil the execution and outflow qualities of Karanja oil are better.

K.Srither et al. [13] discussed from the execution investigation, the warm proficiency of mix DPJ 1 and DPJ 2 were closer to the diesel values. The particular fuel utilization estimations of double biodiesel mixes were tantamount to that of diesel.Pankaj B.et al.[14] analyzed the higher centralization of the mixes found to enhance brake warm effectiveness. Jatrophaand Karanja biodiesel mixes give a decent change in brake thermal effectiveness, because of the extra lubricity and oxygen content is the conceivable purpose behind it. Siddalingappa R et al.[15] investigated the particular fuel utilization to build up the same measure of engine power was observed to be increasingly this might be because of low calorific estimation of the considerable number of mixes. The thermal effectiveness of K15 was well practically identical with that of diesel.

Dr.V.Nagaprasand Naidu et al. [16] found that the examinations propose that mix of Karanja biodiesel blend– B20 is the ideal mix which can deliver better values with pure diesel for diesel motors similarly as execution and emanations were considered. With the goal that it can be utilized as the distinct option for diesel M.Goudilyan et al. [17] discussed the brake thermal efficiency increments with expansion in added substance rate of the biodiesel contrasted and immaculate diesel. Brake particular fuel utilization is discovered most astounding for unadulterated biodiesel at all shifting burdens as a result of high unpredictability, low heat substance, and high consistency. Swarp Kumar Nayak et al. [18] analyzed fumes gas temperature is discovered most astounding for immaculate biodiesel and tends to diminish with expansion in added substance rate in biodiesel.

II. MATERIALS AND METHODS

A. *Modification of Properties of Bio-Fuels: Trans-esterification*

Trans-esterification is a chemical reaction that aims to substituting the methanol and sodium hydroxide (NaOH) with pongamia oil blend. The blend is heated up to 65◦**c** in the container and cooled with atmospheric room temperature. From these processes oil was converted into bio diesel mixture. After transesterfication processes the oil mixture converted into two different layers in the container. Due to this pongamia based bio-diesel separated into high density and low density layers. By using of distilled water filter the low density blend from container. This process will do for all the blend ratios.

Table 1 shows the properties of pongamia based bio-diesel before transesterification process. From this table viscosity of different blends is very high. It is not a suitable alternative fuel for the engine due to abnormal combustion. Thus trans-esterification process should be conducted. After pongamia based bio-diesel processes the viscosity reduces. Table 2 gives the value after transesterification process**.** It shows the kinematic viscosity of the pongamia oil was reduced. Simultaneously the flash and fire point of the different oil blends increased. The calorific value of blends also increased.

B. *Effects of trans-esterification on fuel properties*

Table 1: Properties of oil before trans-esterification process.

Oil	Kinematic viscosity (Cst)	Flash point ◦c	Fire point ◦c	Calorific value (KJ/kg)
Pure Diesel	2.86	33	37	42
Pongamia Oil	30.55	238	245	39.814
95D:5P	3.52	35	44	41.1

90D:10P	5.055	38	47	39.98
85D:15P	5.77	39	50	37.3
80D:20P	7.35	43	52	37.76

Table 2: Properties of oil after trans-esterification process.

Oil	Kinematic viscosity (Cst)	Flash point °c	Fire point °c	Calorific value (KJ/kg)
Pure Diesel	2.86	33	37	42
Pongamia Oil	16.4	90	115	37.65
95D:5P	3.06	38	41	41.05
90D:10P	3.43	43	40.8	40.5
85D:15P	3.75	45	52	39.34
80D:20P	3.92	48	56	38.42

III. EXPERIMENTAL SETUP

The test engine used was a single cylinder, water cooled, 4-stroke, Electrical loading Diesel engine and the experimental setup is shown in Figure 1. The Engine Specifications are given below:

A. Engine Specifications

Manufacturers	:	Kirloskar
Power	:	3.75 kW/ 5HP
Base	:	114.3mm X 139.4mm
Compression ratio	:	19:1.8
Speed	:	1500 rpm
Brake drum radius	:	0.2125 m
Orifice Diameter	:	0.02m

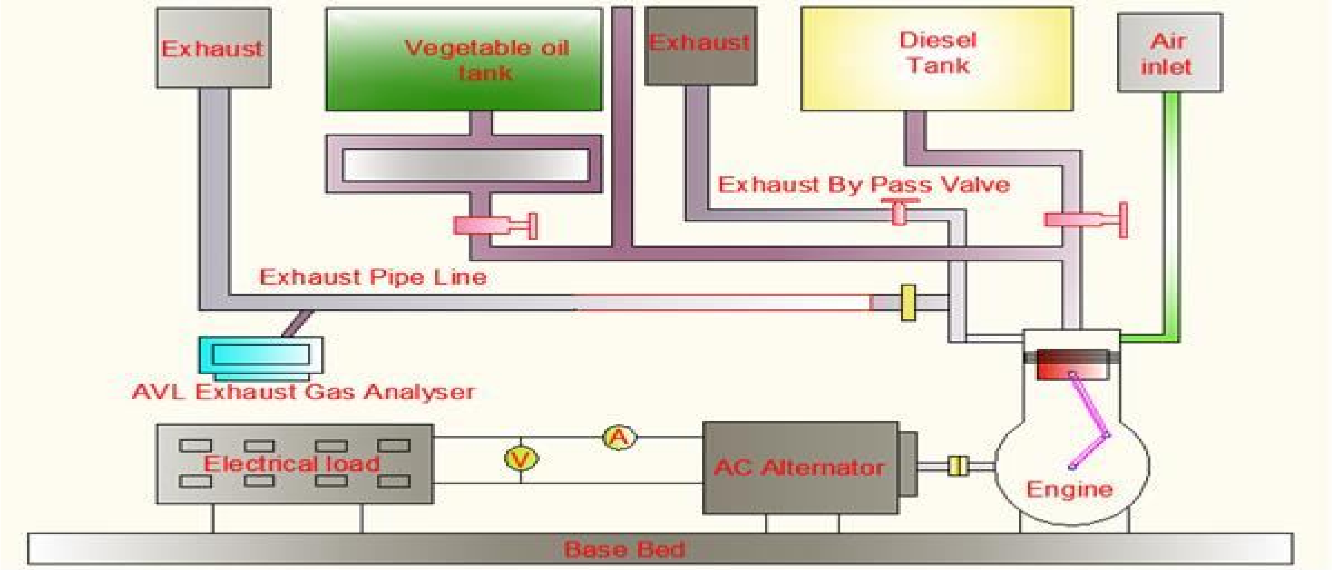

Fig 1: Schematic diagram of experimental setup

IV. RESULTS AND DISCUSSION

The engine is tested for different load conditions to determine the various efficiencies of the engine and heat distribution also calculated. The results are discussed as below.

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A. Brake Thermal Efficiency [BTE]

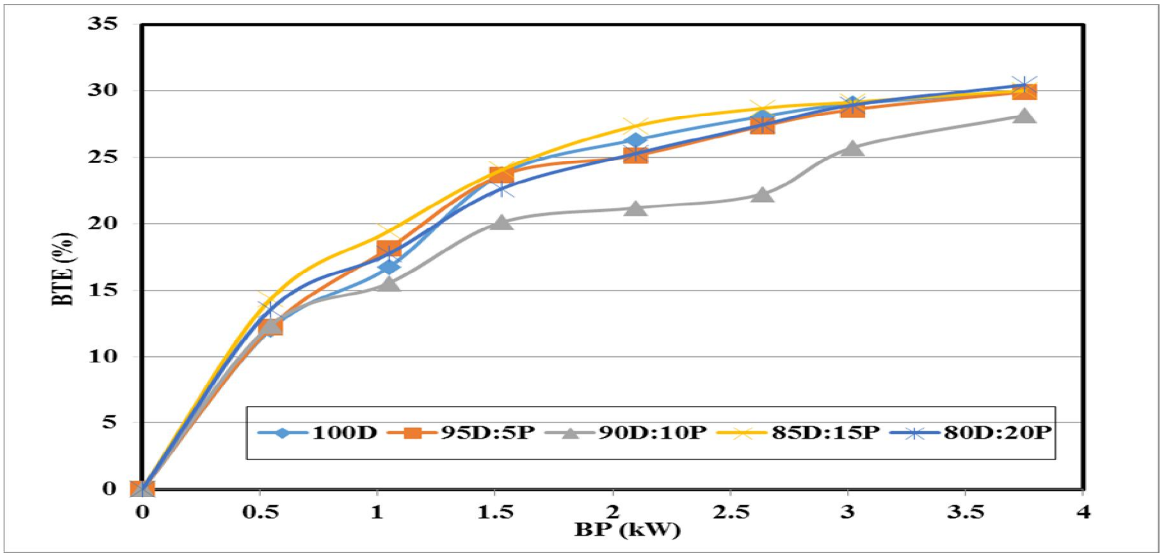

Fig 2: Brake thermal efficiency versus brake power output

The Brake Thermal Efficiency of the engine is used to analyze how the heat energy is converted into useful mechanical work**.** Figure 2 represents brake thermal efficiency versus brake power output for the various bio diesel blends, with various proportions. It is seen that the brake thermal efficiency with pongamia oil is higher than diesel in part load condition. With increase in load condition the brake thermal efficiency starts to decrease from the initial values. At full load condition, 95D: 5P gets higher thermal efficiency and 80D: 20P blending is the lowest. The brake thermal efficiency of pongamia oil in diesel blend is always 90D: 10P lower than diesel fuel operation. The engine runs at economical speed while BTE increased. At part load condition thermal efficiency is less compared to full load conditions.

B. Indicated thermal efficiency [ITE]

The figure 3 represents indicated thermal efficiency versus brake power output for the bio diesel blends, with various proportions. It is seen that the indicated thermal efficiency of 95D: 5P ratio blend is higher than various bio diesel blends at full load condition.

While increasing the pongamia content in diesel, the ITE will be decreased. The 90D: 10P ratio blends has less ITE compared to other blends. The ratio of 85D: 15P blends has initially high efficiency at normal load condition. There is slight difference between 95D: 5P and 85D: 15P blends.

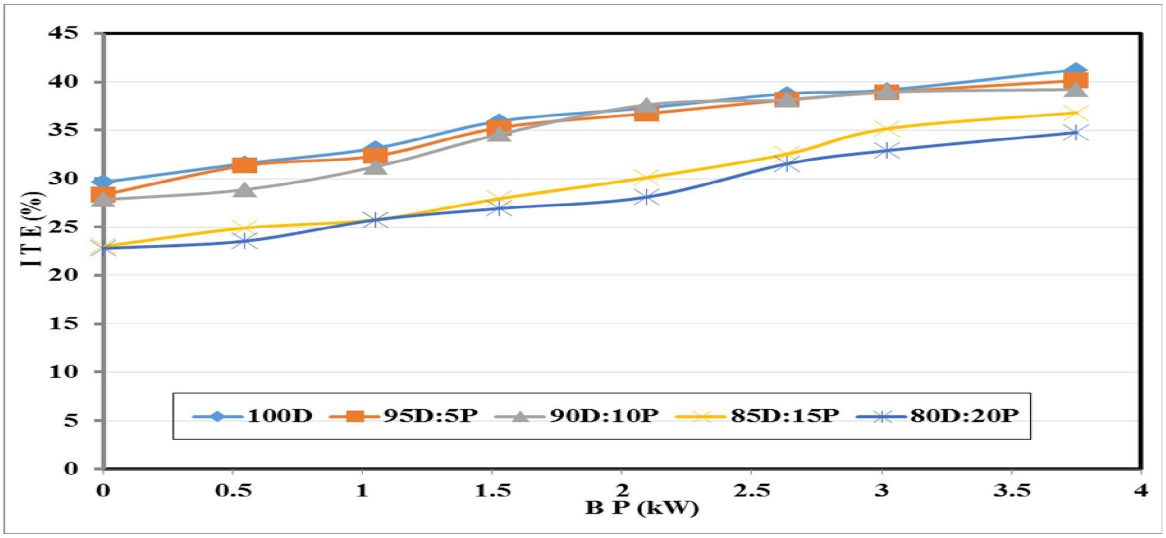

Fig 3: Indicated thermal efficiency versus brake power output

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C. Mechanical efficiency [MECH]

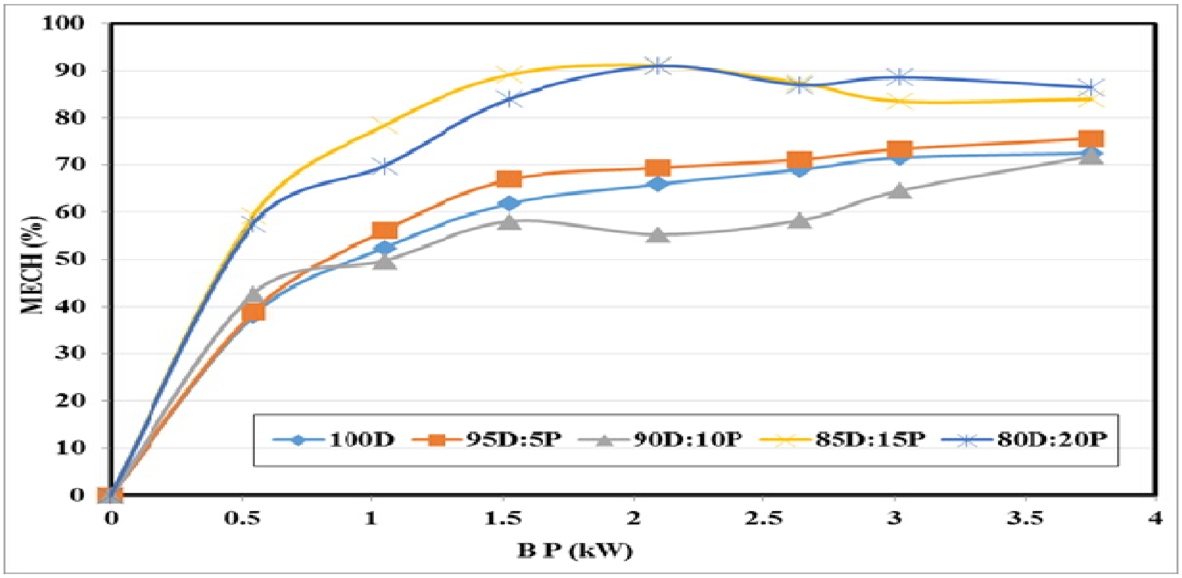

Fig 4: Mechanical efficiency versus brake power output

The Figure 4 represents mechanical efficiency versus brake power output for the bio diesel with various proportions.
It is seen that the mechanical efficiency of pongamia oil is same as diesel for all load conditions. With increase in load condition the mechanical efficiency remains same from the initial values. In full load condition, 95D: 5P ratio blend efficiency is same as 80D: 20P of blends. The analyze gives mechanical work was considerably same for all the blend ratios. While increasing brake power simultaneously mechanical efficiency also increased.

D. Heat in Cooling Water [HCW]

The Figure 5 represents heat in cooling water versus brake power output for the bio diesel blend with various proportions. For 80D: 20P blends more engine heat is lost in cooling medium. Because the blend ratio is high. The 95D: 5P blend ratio initially very less amount of heat dissipations and increasing with load significantly. The 85D: 15P biodiesel blends behaves moderately. As heat dissipation rate increases along with load, more amount of cooling water supply required for maintaining engine heat at normal condition.

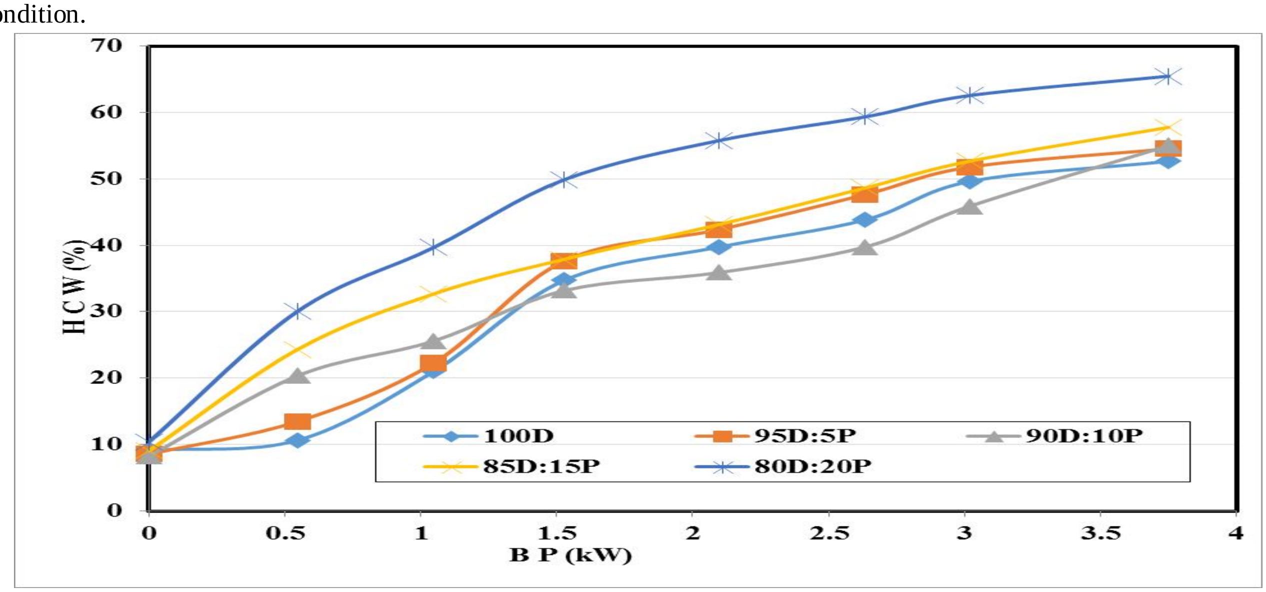

Fig 5: Heat in cooling water versus Brake power output

E. Specific fuel consumption [SFC]

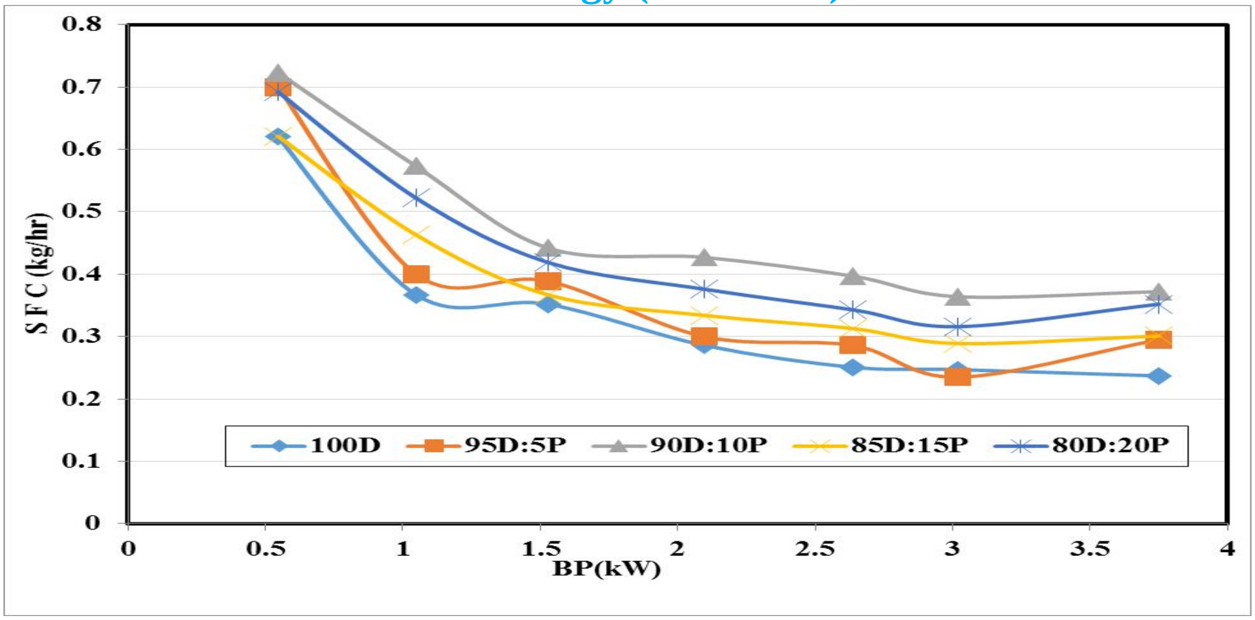

Fig 6: Specific fuel consumption versus brake power output

It describes the amount of fuel burnt to useful torqe for 1 hour. Figure 6 expresses that fuel intake is higher initially than normal load conditions, as the rich fuel mixture comes into combustion chamber. At running condition the fuel will be stochometric and it is inversly propotional to the thermal efficiency of the engine. From graph, SFC 95D:5P ratio blend has more fuel consumption and the 85D:15P ratio blend has good fuel consumption for full load and part load condition.

F. Total fuel consumption [TFC]

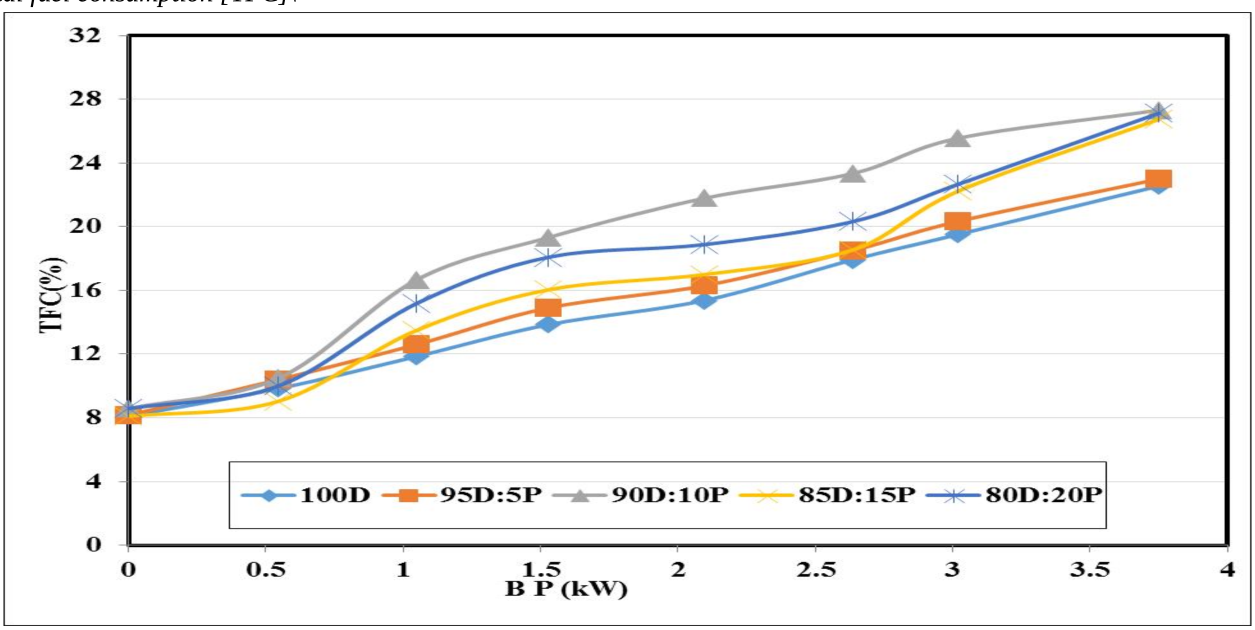

Fig 7: Total fuel consumption versus brake power output

Total fuel consumption is best parameter for considering economical fuel supply. Figure 7 gives total fuel consumption for obtained brake power. Maximum fuel is consumed for 90D: 10P ratio blend. There is a small variation occurred at 80D: 20P ratio blend. The 85D: 15P and 90D: 10P blends have better fuel consumption. TFC increases for high viscous 85D: 20P blend ratio.

G. Heat in exhaust gases [HEG]

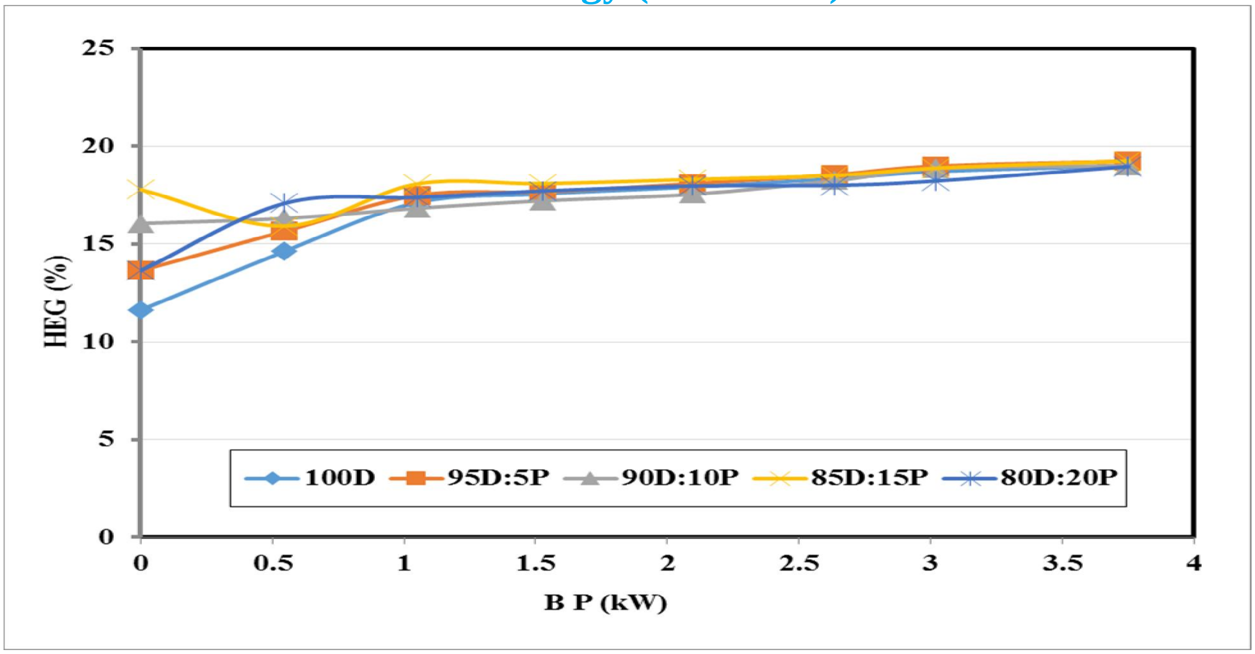

Fig 8: Exhaust gas comparison for different brake powers

Heat inexhaust gas is compared with different brake powers in Figure 8. Heat atinitial load condition 85D: 15P blend ratio is high and it is remains same with 95D: 5P ratio blend. The 90D: 10P and 80D:20P ratio blends has less heat at exhaust condition.Whenever the blend ratio is increased simultaneously exhaush gas temperature will decreased.

H. Unburnt hydrocarbon [UBHC]

The hydrocarbon emission is compared with brake power for different bio diesel blend is plotted in the graph with constant engine speed. Figure 9 it is observed that increasing the load and brake power the hydrocarbon emission is slightly increased.

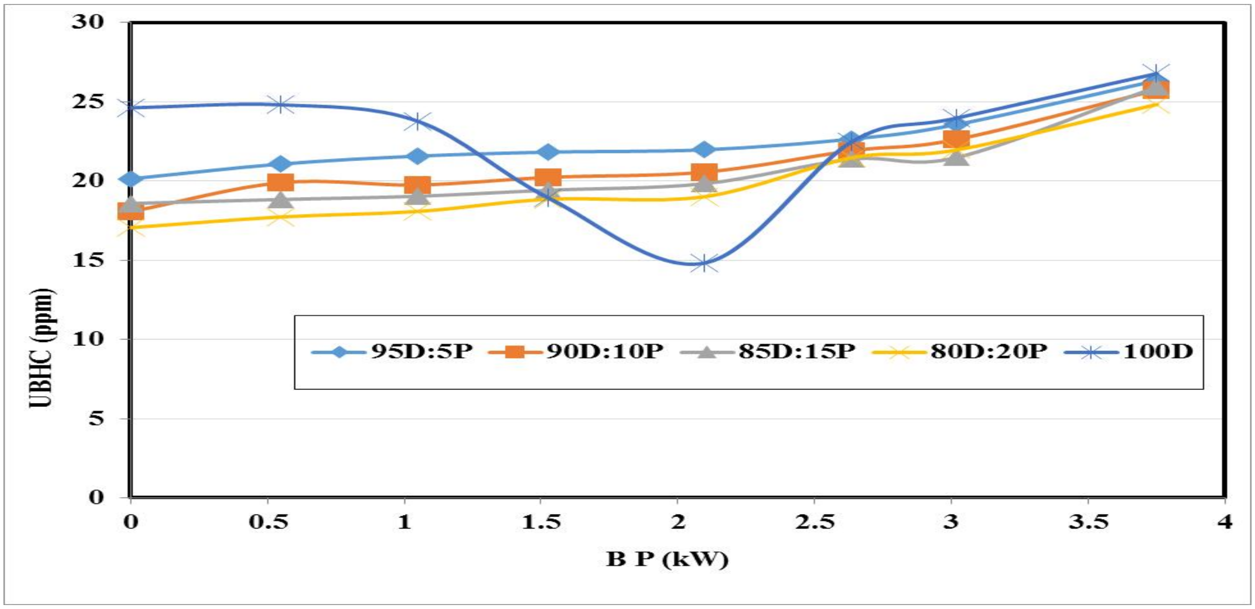

Fig 9: Unburnt Hydrocarbon Emission

The hydrocarbon emission of diesel is less than bio diesel mixtures at full load condition. In no load condition, the hydrocarbon emission of diesel is higher than other bio diesel blends. In 80D: 20P ratio blends, less hydrocarbon emission is produced compared to other biodiesel blends and diesel.

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I. Oxygen [O2]

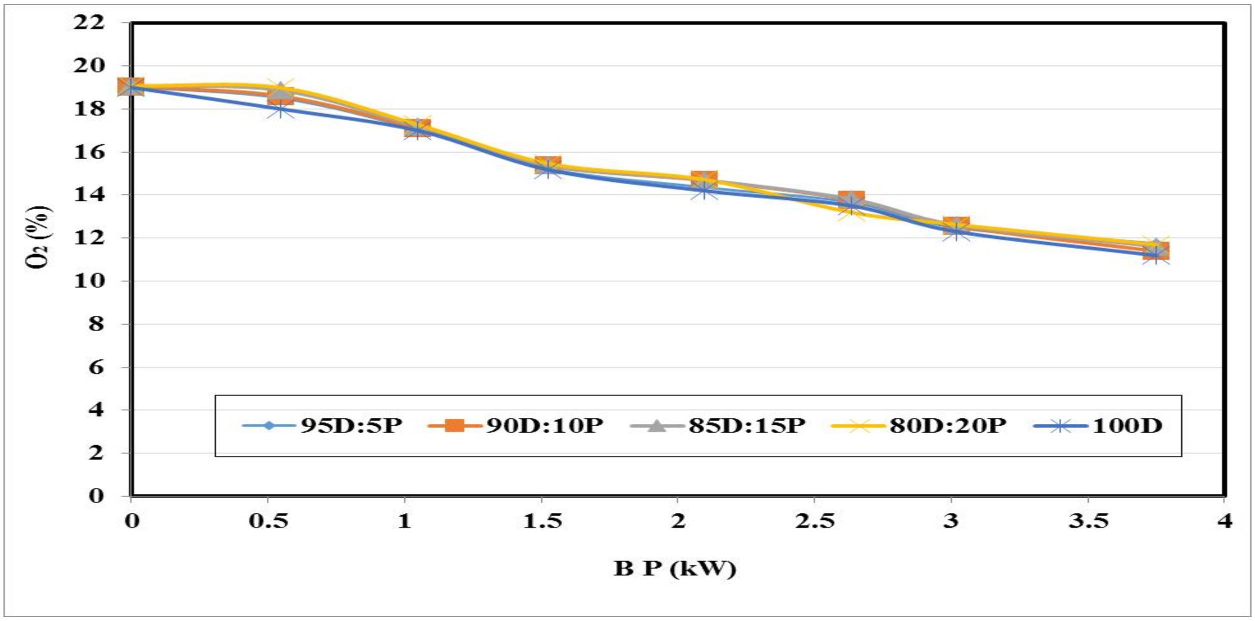

Fig 10: Oxygen Emission

The oxygen liberated is compared with brake power for different bio diesel blends is plotted in Figure 10 with constant engine speed. From this graph, it is observed that whenever the brake power is increased the oxygen emission continuously reduced. At ideal condition, the oxygen liberated is same for both diesel and bio diesel blends. At complete burning of fuel, the oxygen content is decreased continuously. At full load condition oxygen in the exhaust of the diesel is lower than other bio diesel blends.

J. Oxides of Nitrogen emission [NOx]

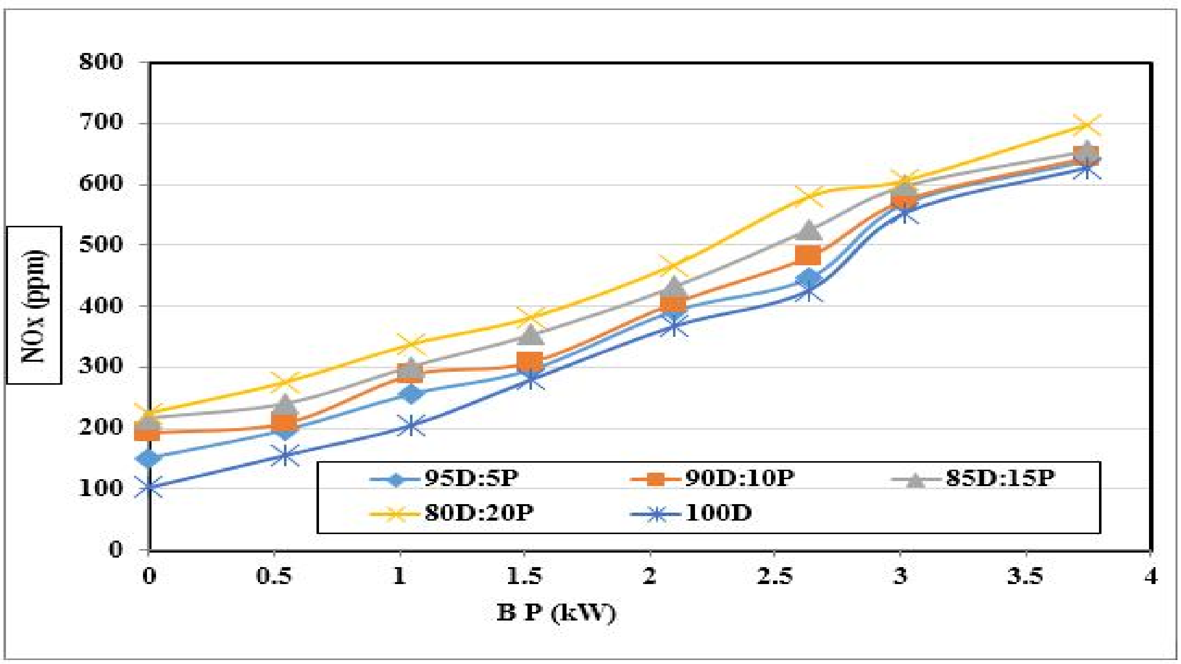

Fig 11: Oxides of Nitrogen emission

The oxides of nitrogen emission are compared with brake power for different bio diesel blends is plotted in Figure 11 with constant

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engine speed. From this graph, it is observed that the oxide of nitrogen emission is continuously increased as the brake power is increased. At initial condition the oxide of nitrogen emission of diesel is lower than other bio diesel blends. The causes of increasing the NO_x emission is high cetane number, high burning temperature, excess oxygen present in the bio diesel. The oxides of nitrogen emission of pure diesel are lower than other bio diesel blends and 80D: 20P blend produces higher NO_x emission.

K. Carbon Monoxide emission [CO]

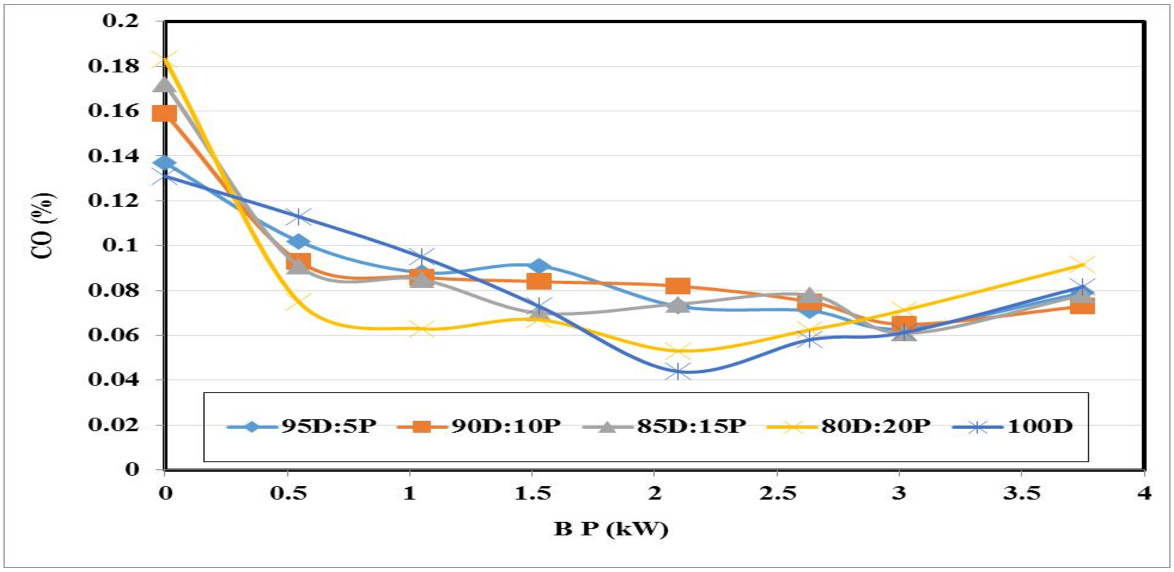

Fig 12: Carbon Monoxide emission

The carbon monoxide emission is compared with brake power for different bio diesel blends are plotted at constant engine speed is shown in the Figure 12. The carbon monoxide emission is slightly decreased at engine half load condition and then increased at full load condition. At ideal condition the carbon monoxide emission of diesel is lower than bio diesel blends. In complete burning of fuel 90D: 10P blend ratio produces less carbon monoxide emission compared to other bio diesel blend with diesel.

L. Carbon Dioxide emission [CO2]

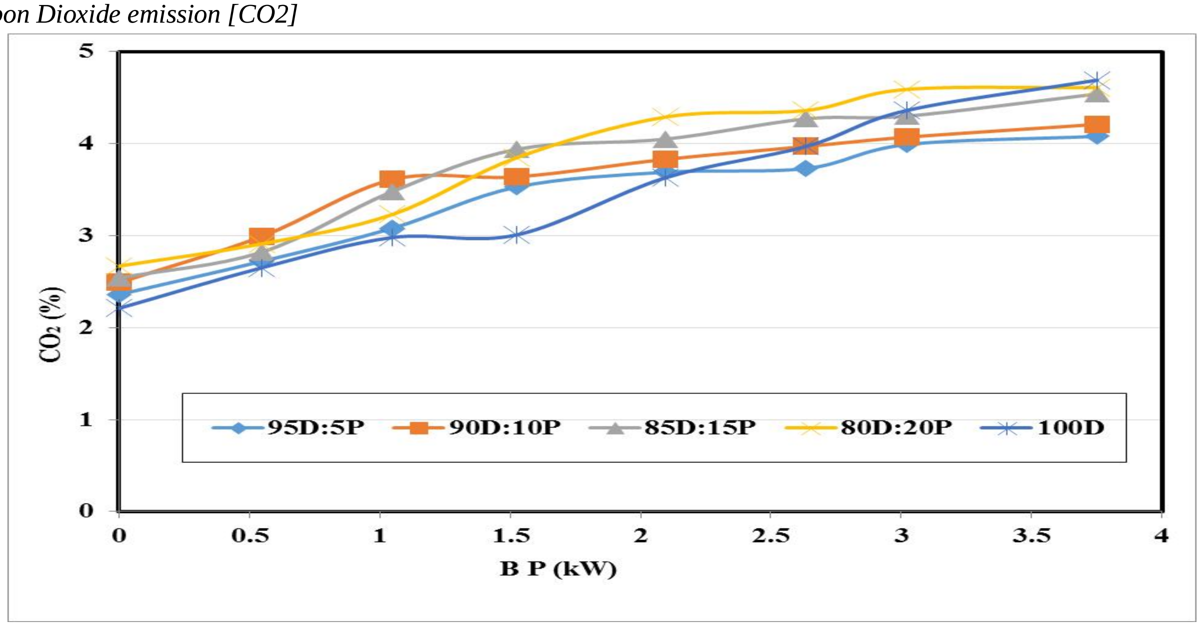

Fig 13: Carbon Dioxide emission

The carbon dioxide emission is compared with brake power for different bio diesel blend is shown in Figure 13 with constant engine speed. It is observed that the carbon dioxide emission is continuously increased with increased in engine load conditions. At initial load condition the carbon dioxide emission of diesel is lower than other bio diesel blends. In this graph the carbon dioxide emission of diesel is higher than other bio diesel blends at full load condition. For the 95D: 5P blends, it produces less carbon dioxide emission than other blends.

V. CONCLUSION

The performance, emission and combustion characteristics of biodiesel derived from pongamia oil and its blends are compared with the conventional diesel fuel. Results are summarized as follows:

A. Diesel engine can perform satisfactorily with pongamia oil and their blends without any engine modifications.
B. As the heating value of biodiesel reduces with increase in percentage of biodiesel in the biodiesel blend, the specific fuel consumption value found to be increases.
C. It is found that there is significant reduction in Unburnt Hydrocarbon and CO for all biodiesel blends when compared to diesel. However, NOx emission is comparatively higher than that of diesel.
D. The test conducted reveals that the 85D: 15P biodiesel blend has better efficiencies and the specific fuel consumption is lower. It also gives lowest unburnt hydrocarbon emission in the exhaust.

VI. NOMENCLATURE

100D	100% of Pure Diesel
95D: 5P	95% of Diesel + 5% Pongamia Methyl Easter
90D: 10P	90% of Diesel + 10% Pongamia Methyl Easter
85D: 15P	85% of Diesel + 15% Pongamia Methyl Easter
80D: 20P	80% of Diesel + 20% Pongamia Methyl Easter
BTH	Brake Thermal Efficiency
ITE	Indicated thermal efficiency
HCW	Heat in cooling water
HEG	Heat in exhaut gases
MECH	Mechanical efficiency
SFC	Specific fuel consumption
TFC	Total fuel consumption
UBHC	Unburnt hydrocarbon
O2	Oxygen
NOx	Oxides of Nitrogen
CO	Carbon Monoxide
CO2	Carbon Dioxide

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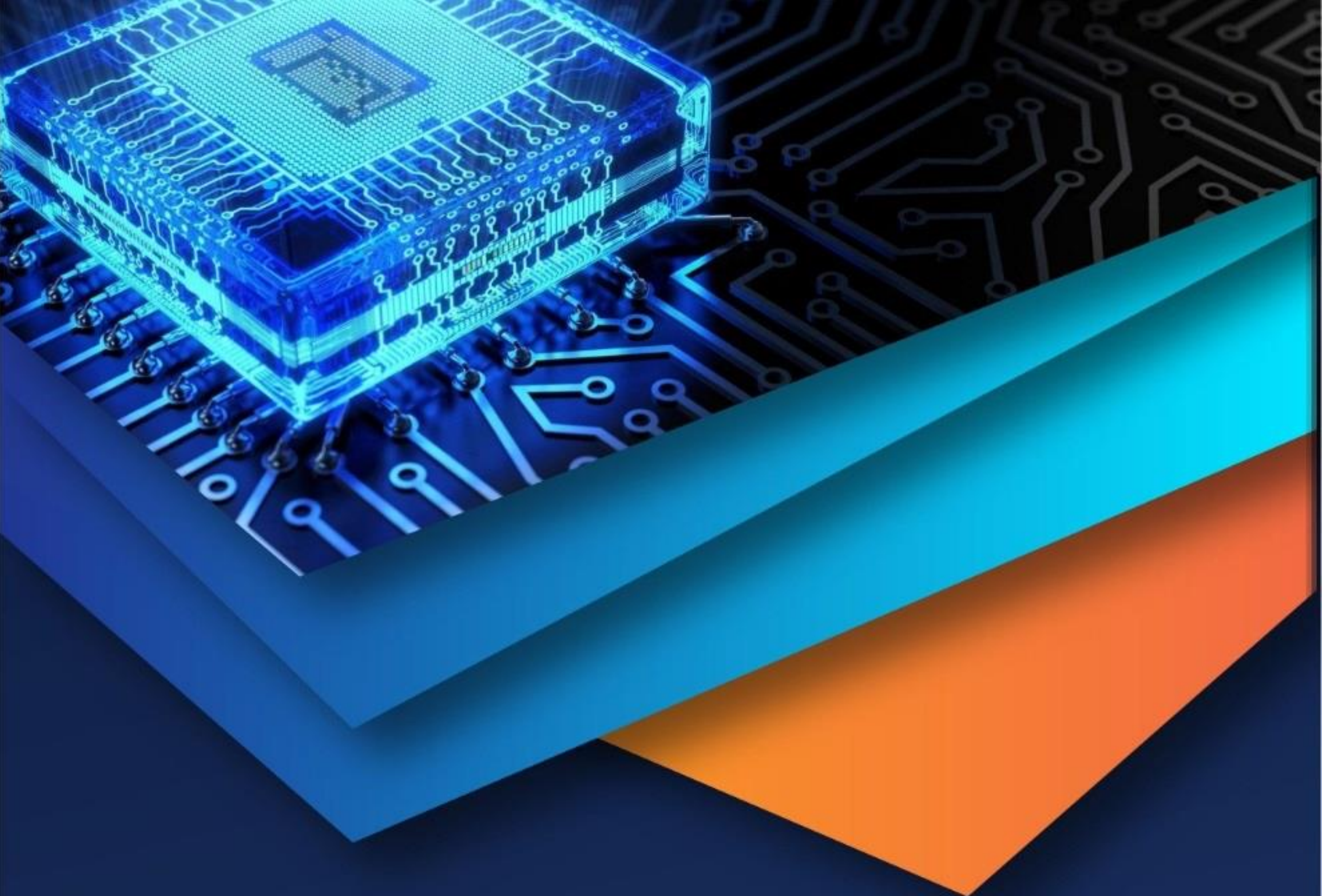

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