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# PERFORMANCE & EMISSIONS CHARACTERISTICS OF CI ENGINE USING TAMARIND BIODIESEL BY KOH, Al2O3 AS ADDITIVIES

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## ABSTRACT

Day by day the air pollution levels are drastically increasing in our atmosphere. The main reason to cause this effect is by using fossil fuels in automobiles, from this the unburned carbon particles, HC, $CO_2$, particulate matters are directly releases into the atmosphere. The Bio fuels are one of the better and best solution to the global energy crisis, global air pollution. For that, in this present study we are going to study the performance and emission characteristics of Tamarind seed oil Bio-diesel (TSO). The blends of Tamarind seed oil with additives Potassium Hydroxide (KOH), Aluminium Oxide ($Al_2O_3$) are going to use in this and analyze their performance and emissions characteristics with performance and emission characteristics of diesel. In this work experiments are conducted on VCR diesel engine by using the Tamarind seed biodiesel as an alternative fuel. Further experiments are conducted on VCR engine by varying the concentration of bio fuel ranging from 0 to 0.08％, and loads（N）ranging from 0 to 18 N. Performance, and Emissions measured by using Exhaust Gas Analyzer. From the experiments it is observed that the brake thermal efficiency（BTE）is high at 0.06％ concentration and fuel consumption is also reduced. The Carbon monoxide (CO), Hydrocarbon (HC) and Carbon dioxide ($CO_2$) emissions are reduced and the $NO_X$ emissions are increased. This is due to complete combustion of fuel.

## INTRODUCTION

In recent times, the rapid depletion of crude oil resources, rising environmental pollution concerns and spikes in fuel prices have neccessitated a greater focus on the need to exploit biodiesel as an attractive renewable feedstock for the diesel engine. Needless to say, biodiesel is widely regarded as an environment-friendly, economical and abundantly available resource. Over the past many years, reasearchers have examined different feedstock for biodiesel production, which can be derived from jatropha curcas, corn seed oil, Pongamia pinnata, mahua seed oil, sunflower, soybean, etc., and carried out extensive studies on their effect on the performance parameters in a diesel engine. Many literature studies have been conducted on different form of biodiesels across the globe.

The need for alternative fuel in agriculture, transportation, power and industry sectors is increasing the trend day by day. The global warming potential (GWP) and ozone depletion potential (ODP) are also adversely affected by the greenhouse gases emitted from the combustion of fossil fuels, other industrial sources, and wastes. Various efforts were put on identifying different sources of biodiesel as alternative fuels. Biodiesel is one of the major eco-friendly renewable resources available to replace the Petroleum fuels. Transport vehicles do not require any engine modification, since the Biodiesel is the best feasible choice of renewable energy source. The Heat content value of Biodiesel is increased by different techniques. To attain the specific requirements of fuel different additives and chemical compounds are to be added. Therefore the blended fuel chemical and physical properties are improved.

From the past two decades, many researchers ensure that biodiesel fuels produce no sulphur dioxide and less aromatic hydrocarbon emissions. Biodiesels are renewable, less poisonous, and biodegradable and their combustion characteristics are similar with petroleum fuels. Biodiesel properties are similar to that of petroleum fuels and they can be used as sole fuel or blended with diesel in diesel engines without any modification is the advantage to use it. Major types of the alternative energy sources are solar energy, wind energy, natural gases, bio-gas and nuclear energy. All these energy sources fall into the category of renewable energy sources and are pollution free. The fuels of biological origin can provide a solution for this crisis. Biodiesels have the capability of replacing fossil fuels because of their remarkable properties like less carbon emissions, high calorific value which is almost close to the calorific value of Diesel and is a clean energy.

**Literature review**

In this section characterization of biodiesel, performance and emission characteristics are carried out by earlier researchers with regards to the use of different types of biodiesel concentration as a fuel in diesel engines are presented.

Harish Venu at al**.** the current experimental work deals with usage of tamarind oil biodiesel as a potential alternative feedstock for existing unmodified single cylinder DI diesel engine. Experiments were performed with B10, B20, B100 and diesel fuel at engine loads of 25%, 50%, 75% and 100% respectively. Based on experimentation, Highest in-cylinder pressure is observed for B10 blend (65.59 bar) followed by B100 (64.39 bar), B20 (63.63 bar) and diesel (63.21 bar) and emission wise, B100 blend exhibits highest NOx emission formation, CO emissions of biodiesel blends were lower than Diesel because of the higher cetane indexed biodiesel blends which lowers the chances of formation of fuel rich zones which subsequently lowers the CO emissions. $CO_2$ emissions of B100 blend is of highest at 100% engine load condition, HC emissions of B10 and diesel fuel is highest in comparison with other concentraions owing to the fuel- air mixture of B10 blend becoming much leaner for supporting the flame propagation thus making the mixture very leaner followed by higher unburnt hydrocarbon formation**.**

Dhana Raju at al**.** the abundant availability of tamarind seed at almost zero price makes it an attractive option for large-scale application in diesel engines in a country like India. The novel use of tamarind seed methyl ester offers multiple advantages that include better diesel engine characteristics, significantly lower levels of emission, economical, highly sustainable and eco-friendly. The maximum BTE found from the experimental results of TSME20 blend is 35.74%, which is 1.56% higher thermal efficiency than diesel at peak load conditions. Remarkably, the present work demonstrates significant reductions in smoke capacity, HC, and CO emissions with Alumina oxide nanoparticle dispersed in TSME20 biodiesel blend. It achieves a smoke capacity of 87.4% and CO emission of 56.6% lower than diesel at full engine loading condition. However, the

NOx emission is found higher in the TSME20 at 60% load blended fuel but it is lower than the TSME20 40% blend.

Kishorea et al**.** the present experimental work explores the rich potential of a novel biodiesel in the form of tamarind seed oil for use as a renewable fuel in diesel engines. The abundant availability at almost zero price makes it an attractive option for large scale application in diesel engines in a country like India. The novel use of tamarind seed methyl ester (TSME) offers multiple advantages that include better diesel engine characteristics, significantly lower levels of emission, economical, highly sustainable and eco- friendly. Among all the tested fuels, TSME 20ppm showed better diesel engine characteristics. Remarkably, the present work demonstrates significant reductions in HC and CO emissions with alumina nanoparticles dispersed in TSME biodiesel blend. Finally, from these experimental findings, it is concluded that TSME 20 ANP-2 biodiesel blend registers better performance values at significantly lower emission levels when compared to other tested fuels. This research work is distinctively original in applying nanoparticles additives to the tamarind biodiesel blend, thereby significantly enhancing engine performance as well asemission characteristics with huge potential for large scale commercial application.

Jayashri N Nair et al**.** from the experiment, focussed on engine performance and emission characteristics of CI engine using Tamarind Biodiesel (TB) blends against Neat Diesel (ND). TB5, TB10, TB15 and ND were used for test. The BSFC values for TB blends were lower compared to ND as percentage increase of brake power with load was higher in comparison to expending fuel. TB15 showed the least BSFC value. BTE of TB blends were higher than the ND which can be accounted to high oxygen content of the biodiesel which assists in efficient combustion. TB blends showed excellent emission results. All the emissions were reduced compared to the ND. TB10 blend displayed optimum results for performance and emissions of ND engine. It can be deduced that TB can be used without any modification in engine. The investigation leads towards exploring capability of Tamarind seed oil as alternative fuel.

Harun Kumar et al**.** the analysis of performance and emission characteristics of a direct injection diesel engine operated with TSME20 has been performed at retarded and advanced injection timing and the results compared with the results obtained on a diesel engine operating at standard injection timing. The conclusions made based on the experimental results are as follows. 3.18% improvement in brake thermal efficiency is observed for the engine operating with TSME20 at the injection timing of 19° bTDC over standard injection timing. Lower brake specific fuel consumption of 0.282 kg/kWh is found at the retarded injection timing. NOx emission levels are reduced by 31.34% at full load with retarded injection timing compared to standard injection timing of TSME20 blend. Exhaust emissions such as CO, HC and smoke are lowered by 17.3%, 57.3% and 8.1% at retarded injection timing over standard conditions.

Kishore et al**.** the abundant availability at low price makes the tamarind seed methyl ester is an attractive option for large scale application in diesel engines in a country like India. The novel use of Tamarind seed methyl ester (TSME 20) offers multiple advantages that include better diesel engine characteristics, significant lower levels of emission, economical, eco- friendly and highly sustainable. An experimental approach has applied to optimize the intake parameters of diesel engine for evaluation of performance Signal to Noise (S/N) ratio. Larger is better quality

characteristic is carried out for optimization of BTE and smaller is better quality characteristics are chosen for BSFC, HC, NOX and smoke opacity. It is found that the injection timing has the most significant influence on BTE; NOX and smoke emissions are highly influenced by EGR rate, followed by Injection Timing (IT) and Injection Pressure (IP). The optimized conditions from the present investigations are IP of 220 bar, IT of 190 and 0% EGR shown the enhanced brake thermal efficiency. The exhaust emissions such as HC, NOX and smoke opacity are lesser at IP of 220 bar, IT of 230 and 20% EGR. The results obtained from the optimization using Taguchi method are in close agreement with the experimental results.
The objective of the present work is to increase the performance of CI engine using VCR system with tamarind biodiesel as fuel, and reduce the exhaust emissions of Carbon dioxide, Carbon monoxide and unburnt hydrocarbons. To control the $NO_X$ Emissions.

**Materials and Methodology**
Transesterification is the reaction of triglyceride (fat/oil) with an alcohol in the existence of acidic, alkaline or lipase as a catalyst to form monoalkyl ester that is biodiesel and glycerol. The existence of strong acid or base accelerates the reaction. The main aim of Transesterification is to reduce the high viscosity of oil which is suitable for Compression Ignition engine. Biodiesel produced from Tamarind seeds oil by base catalyzed transesterification reaction. In this study Methanol is taken as alcohol and potassium hydroxide is the base catalyst.
Raw materials are**:** Tamarind oil, Methanol, Potassium Hydroxide, and Distilled Water.
Steps involved in transesterification process**:** Removal of fatty acids, and Water wash

**Titration process**

- Take 1ml of oil in conical flask with 10ml of ethanol and add 2 to 3 drops of phenphthaline to it.
- Fill the buratte with 1000ml distilled water and mix 1 gram KOH to it.
- Do the titration process until the conical flask solution turn into pink colour.
- The point where we got the pink colour that is the amount of KOH we have to take in the process of removal of fatty acids.

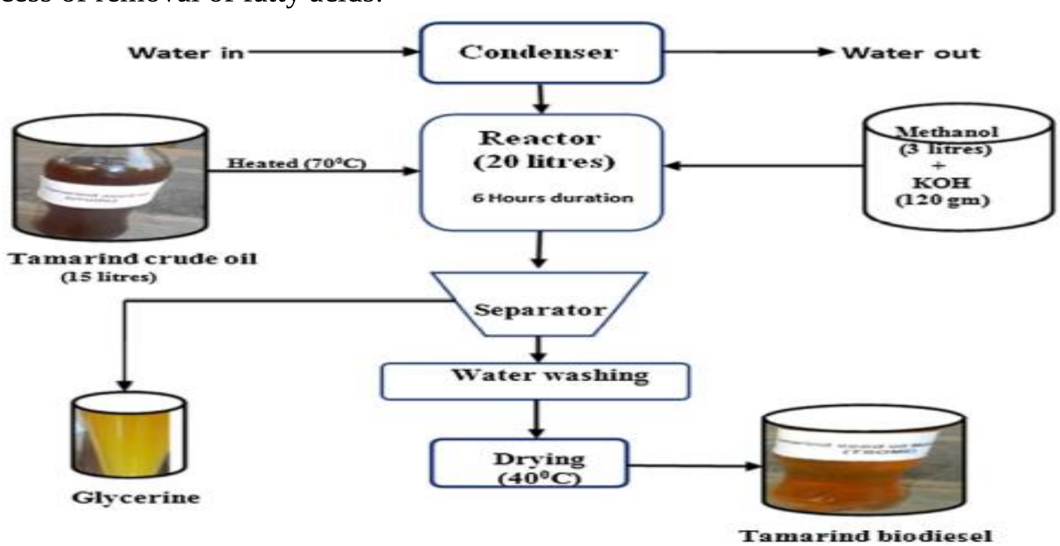


Figure 1: Tamarind seed methyl ester production through the transesterification technique.

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**Removal of fatty acids**

- Take 1000 ml tamarind oil in flask and heat the oil upto 65°C
- Then take 200 ml of methanol in beaker and mix 8 to 10 grams of KOH, shake it well to dissolve all the KOH in distilled water
- Pour the above mixture in 1000 ml heated oil and don't disturb the solution for 24 hours.
- After that there is a formation of cake on the bottom of the flask, fatty acids present in pure tamarind oil.
- Separate the fatty acids from oil then free fatty acids of tamarind oil is formed.

Formation of fatty acids

**Water Wash**

- Take 1000ml of distilled water and mixed with 1000ml glycerides free tamarind Oil and shake well.
- Don't disturb the above mixture for 3 to 4 hours.
- After that there is a formation of monoglycerides on the bottom of the flask and above biodiesel is formed
- Separate the monoglycerides from oil then Biodiesel of tamarind oil formed.

**PROPERTIES OF TAMARIND SEED BIODIESEL**

Table 1: Properties of Tamarind oil

| S.NO | PROPERTIES | DIESEL | BIODIESL |
|---|---|---|---|
| 1 | Density(kg/$m^3$) | 0.832 | 0.842 |
| 2 | Kinematic viscosity40°C (cSt) | 3.72 | 6.84 |
| 3 | Fire point (°C) | 64 | 146 |

| | | | |
|---|---|---|---|
| 4 | Flash point (°C) | 62 | 154 |
| 5 | Calorific value (kJ/kg) | 42500 | 41000 |
| 6 | Cetane number | 48 | 51.2 |

**Experimental Setup:**

The engine setup consists of 4-stroke single cylinder water cooled diesel engine which is coupled to eddy current dynamometer. The whole setup is mounted on mild steel structure. It has also a stand consisting of inlet air box with orifice, fuel tank, fuel measuring unit, speed measuring unit, loading unit, transmitters for air and fuel flow measurements. Rotameter also provided at bottom of stand, which provides cooling water to engine and calorimeter.

The setup consist of four stroke single cylinder naturally aspirated, water cooled diesel engine manufactured by kirloskar with a displacement volume of 661 cc and compression ratio (CR) of 17.5:1. The rated power of the engine at 1500 rpm is 5.2 kW. Experiments are conducted on engine by maintaining constant speed of 1500 rpm. Eddy current dynamometer is coupled to the engine.

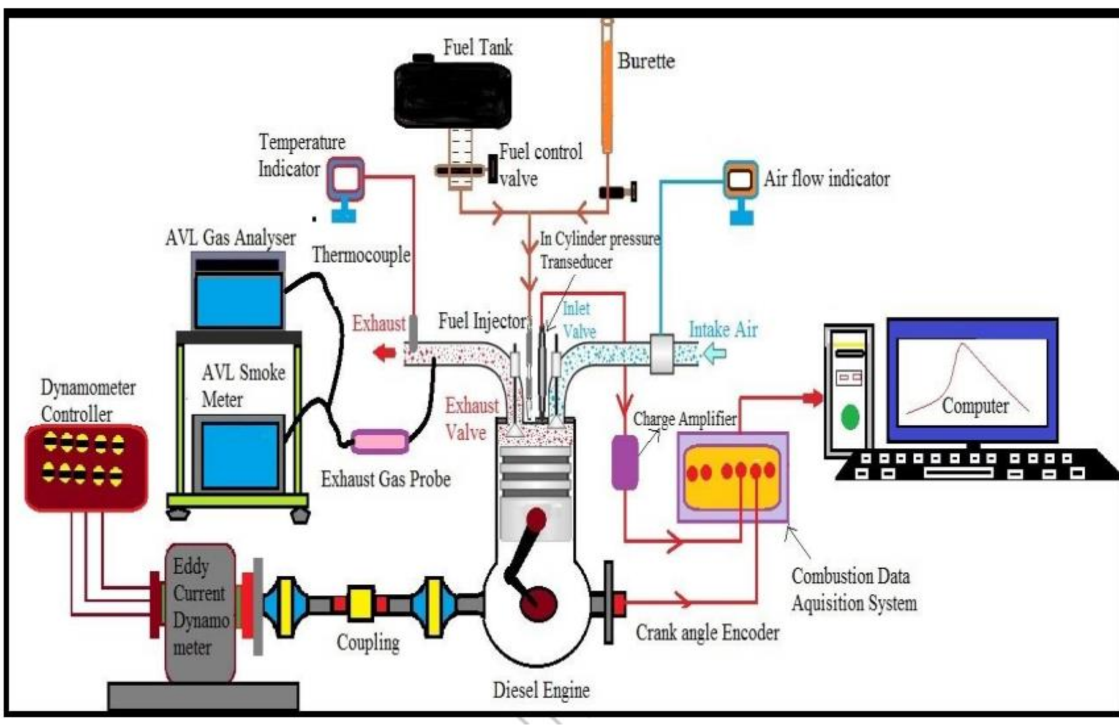

Fig**.** 5**:** Actual Experimental Setup

**Four Stroke Single Cylinder Engine**:

In four-stroke engine, the cycle of operation is completed in four strokes of the piston or two revolutions of the crankshaft. Each stroke consists of 180$^o$ of crankshaft rotation and hence a cycle consists of 720$^o$ of crankshaft rotation. The series of operation of an ideal four-stroke engine are as follows:

1. Suction or Induction stroke: The inlet valve is open, and the piston travels till BDC of cylinder, drawing in a charge of air from atmosphere through inlet manifold. In the case of a spark ignition engine the fuel is usually pre-mixed with the air.
2. Compression stroke: Both valves are closed, and the piston travels up the cylinder by compressing the air inside the combustion chamber. As the piston approaches top dead centre (TDC), ignition occurs. In the case of C.I. engines, the fuel is injected over the piston head by the end of compression stroke.
3. Expansion or Power or Working stroke: Combustion propagates throughout the charge, by rapid increase in the pressure and temperature inside the combustion chamber and forcing the piston down. At the end of the power stroke the exhaust valve opens, and the irreversible expansion of the exhaust gases is termed 'blow-down'.
4. Exhaust stroke: The exhaust valve remains open, and as the piston travels up the cylinder the remaining gases are ejected through exhaust valve. At the end of the exhaust stroke, when the exhaust valve closes some amount of gas residuals will be left; these will dilute the next charge.

**Dynamometer**: The test engine is coupled with an eddy current dynamometer for determining the load with more accuracy. The dynamometer functions according to the eddy current principle and is used to determine the effective power generated by the engine. The engine is set to operate at a constant speed of 1500 rpm. The load of the engine was measured from load cell.

**Performance Parameters:** Brake Power (kW), Brake Thermal Efficiency (%), Fuel Consumption (g/sec), and Mechanical Efficiency (%).

**Emission Parameters:** Carbon monoxide (%), Carbon dioxide (%), Nitrogen oxides (ppm), Oxygen (%), and Hydrocarbon (ppm).

**Experimental test procedure:**

The test engine is operated by Tamarind oil (Biodiesel) by fixing compression ratio (CR) of 17.5:1. The engine is allowed to run with neat diesel at a various loads for nearly 10 minutes to attain the steady state with constant speed conditions. Then the following observations are made.

- The water flow is started and maintained constant throughout the experiment.
- The load and speed indicators are switched ON.
- The engine is started by cranking after ensuring that there was no load.
- The engine is allowed to run at the speed rate of 1500 rpm rev/min for a period of 20 minutes to reach the steady state.
- The fuel consumption is measured in One minute by using stop clock.
- The exhaust temperature was measured at the indicator by using a sensor.
- Then the load is applied by adjusting the knob, which was connected to the Eddy Current Dynamometer.

The experiment is conducted on Kirloskar Variable Compression Ratio, single cylinder, four-stroke, water cooled CI diesel engine with a displacement of 661cc. Engine running with a constant speed of 1500 rpm, rated power of the engine is 5.2 KW. By using of MMI software maintaining constant speed of 1500 rpm. Injection for the cooling of Engine, cooling water is supplied through jackets of engine block and cylinder head.

## Results and discussions

The operation carried with MMI software with diesel engine using tamarind biodiesel is found very smooth throughout the rated load, without any operational trouble. The performance characteristics such as Brake thermal efficiency (BTE), Indicated thermal efficiency (ITE), fuel consumption (FC) and the emissions characteristics such as NOx, HC, CO and $CO_2$ are plotted against the various loads using during operation, namely they are 0% ( No load condition), 20%, 40%, 60%, 80%, 100% ( Full load or Rated load).

### Brake thermal efficiency (BTE)

Figure 5.1 shows the variation of brake thermal efficiency with Loads at different conditions during operation. From the graph, it is noticed that the Brake thermal efficiency is increased with increasing Load. The brake thermal efficiency is high for 0.08% concentration at full load condition which is 43.45%. Where as 0.06% concentration sample has 41.82%, which is almost similar to the diesel.

From figure 5.2 it is shown that the indicated thermal efficiency of 0.08% concentration of tamarind oil sample is almost similar to that of diesel i.e.86.8. Minimum mechanical efficiency observed for base fluid of tamarind seed oil, which is equal to 81.5%.

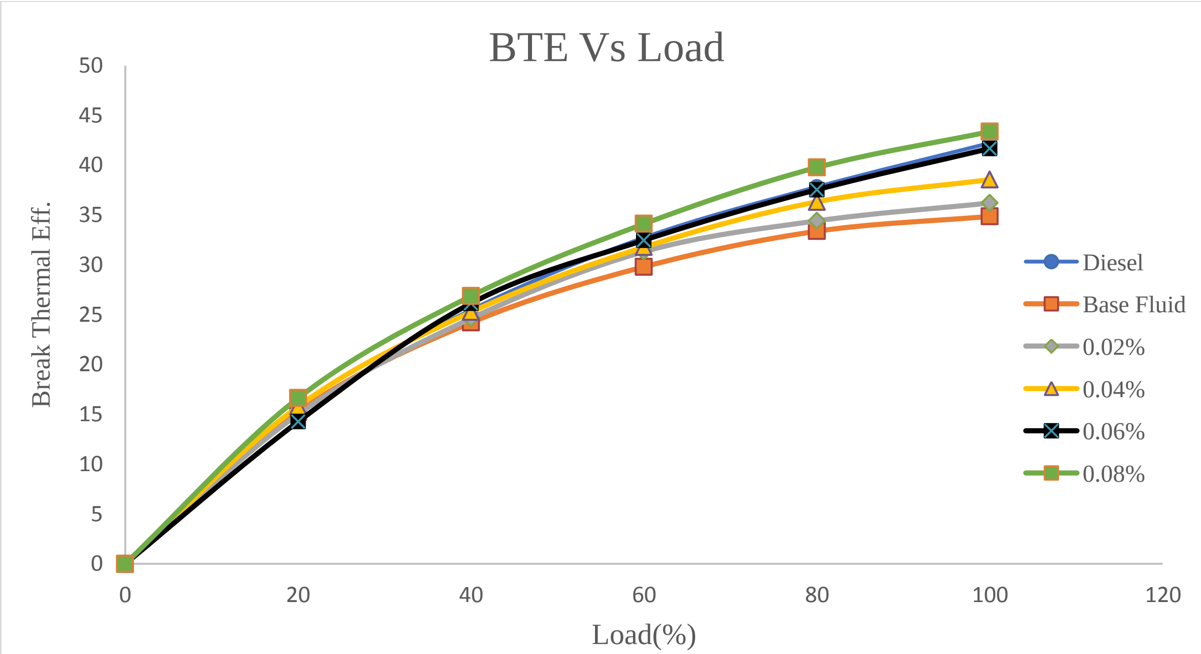


Figure: 5.1 Brake thermal efficiency Vs Load at different conditions during operation

**Mechanical Efficiency (ME)**

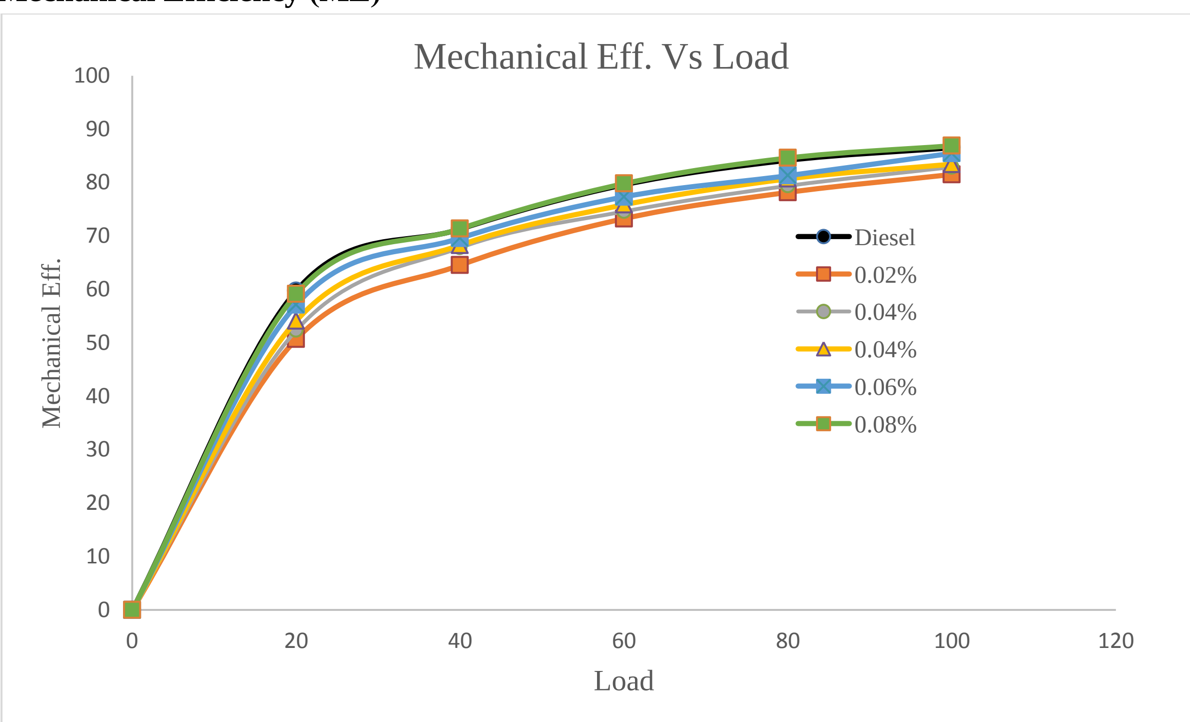


Figure: 5.2 Mechanical efficiency Vs Load at different conditions during operation

**Specific Fuel Consumption (SFC)**

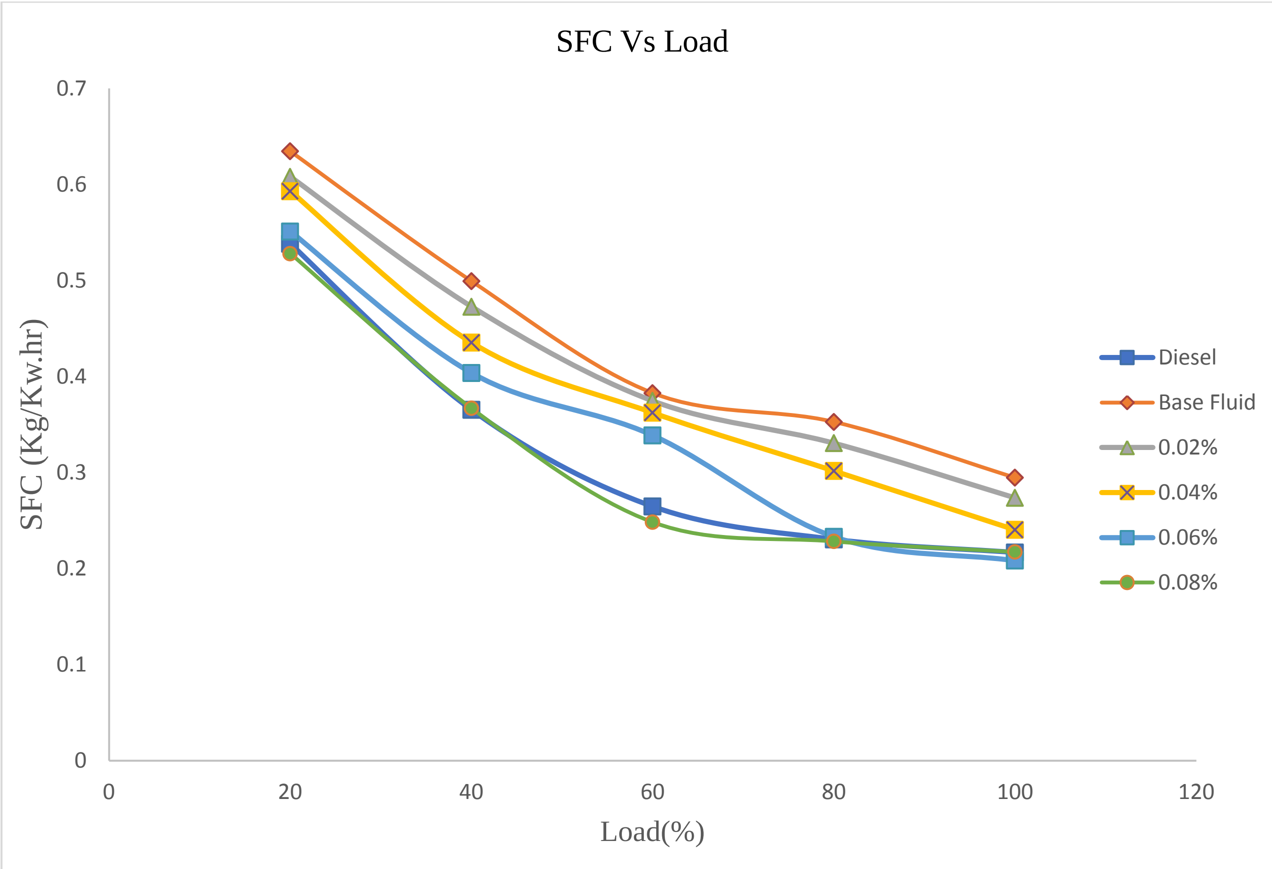


Figure: 5.3 Specific Fuel Condition Vs Load at different conditions during operation

Figure 5.3 shows the variation of SFC with Load, shows that fuel consumption is high for base fluid compared to diesel. By using different concentration samples we can reduce the fuel consumption of diesel engine. From the fig. it was showing that at 0.06% concentration of tamarind oil is low fuel consumption (i.e. 0.2083 compare to diesel = 0.2168) is there compare to the diesel, since the viscosity of tamarind oil is more therefore at higher load condition, better atomization takes place results in low fuel consumed for the rated power.

**EMISSION PARAMETERS**

Effect of increasing the load of diesel engine, we can see the significant increase in engine emissions, those are assessed by comparing variations CO, $NO_X$, $CO_2$ and HC emissions Vs Load for Tamarind biodiesel by using variable compression ratio diesel engine. Effect of increasing the Torque of diesel engine, we can see the significant increase in engine emissions, those are assessed by comparing variations CO, $NO_X$, $CO_2$ and HC emissions Vs Load for Tamarind biodiesel by using variable compression ratio diesel engine.

**CO Emissions**

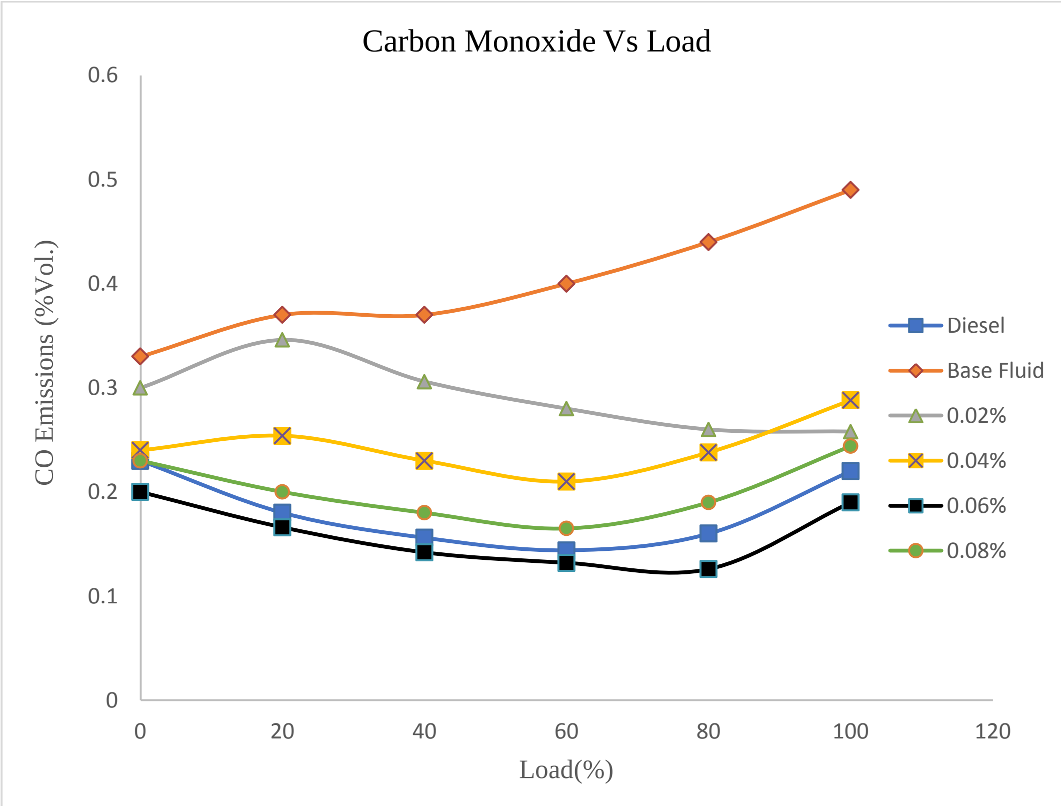


Figure: 5.4.1 Load Vs CO Emissions at different concentration of samples of tamarind oil

**NOx Emissions**

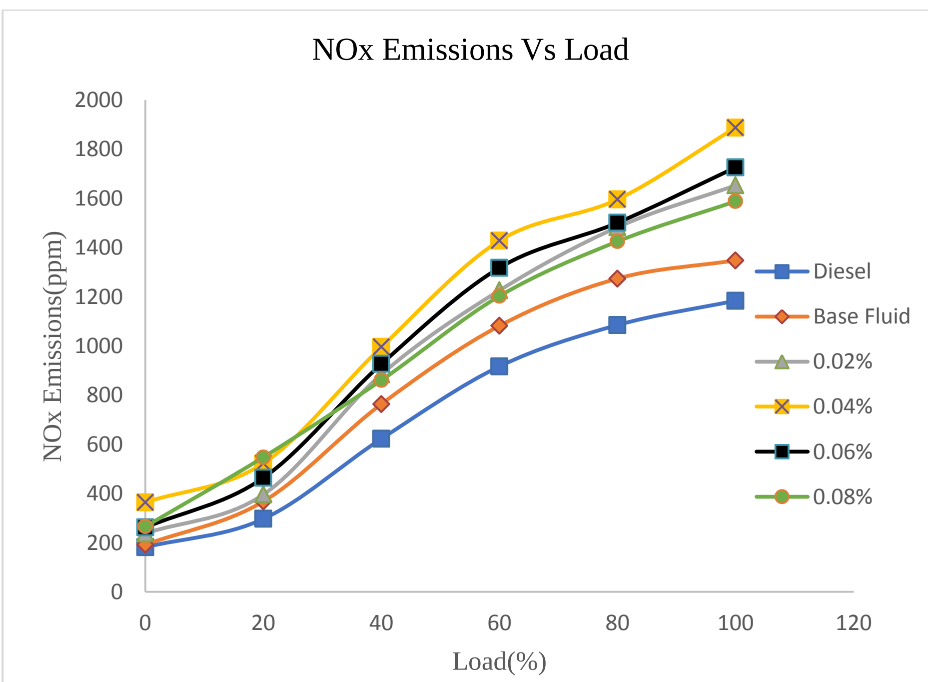


Figure: 5.4.2 Load Vs NOx emissions at different concentration of samples of tamarind oil

**$CO_2$ Emissions**

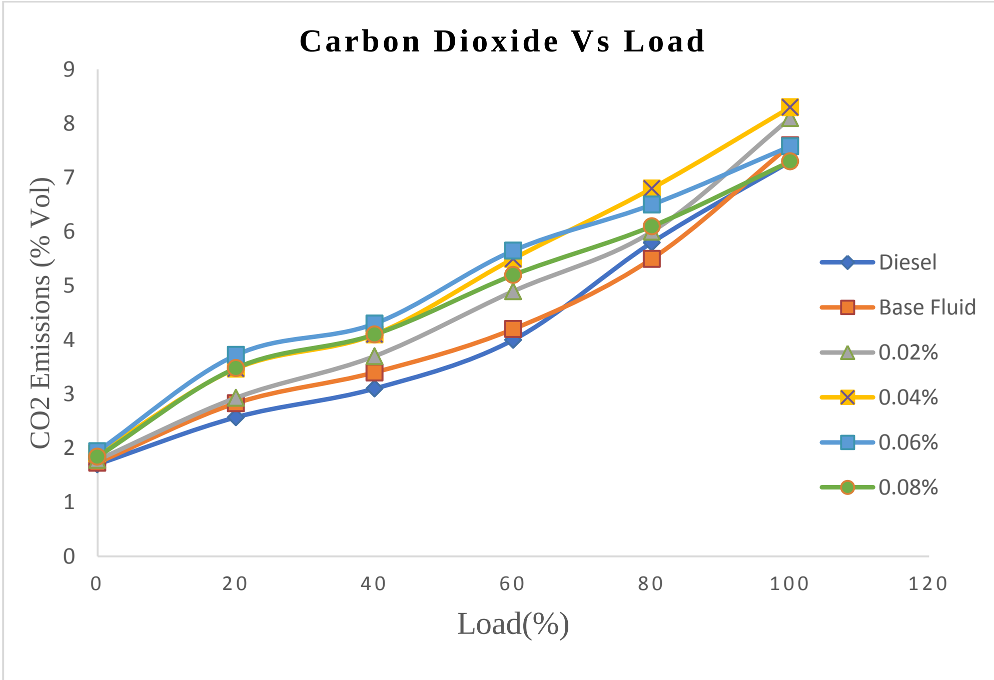


Figure: 5.4.3 Load Vs $CO_2$ emissions at different concentration of samples of tamarind oil

**HC Emissions**

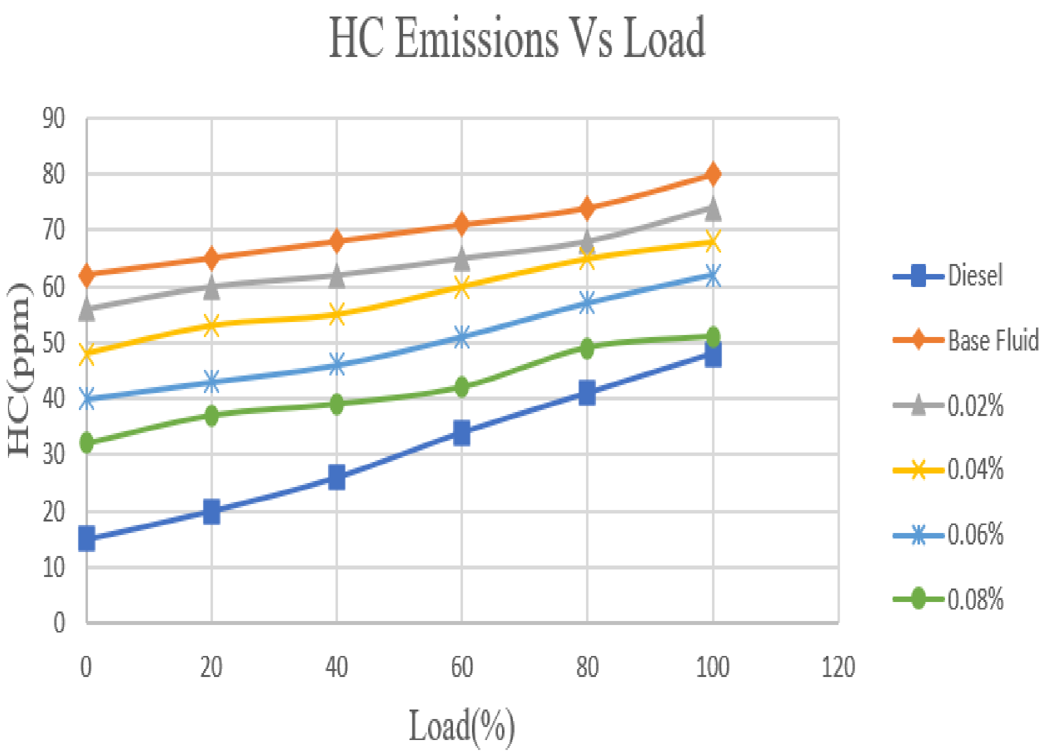


Figure: 5.4.4 Load Vs HC emissions at different concentration of samples of tamarind oil

From figure 5.4.1 it is observed that the CO emissions increased with increasing load. The Carbon monoxide emissions produced low for 0.06% concentration of tamarind oil is low due to complete combustion of the fuel.

Figure 5.5.2 shows that the $NO_X$ emissions are varies with different loading conditions. The $NO_X$ emissions are increased with increasing load. The $NO_X$ emissions are high at full in 0.04% of sample concentration due to high exhaust temperature, where as it was significantly lower for 0.08% concentration of tamarind oil.

From figure 5.4.3 it is noticed that the variation of $CO_2$ emissions with Load. The $CO_2$ emissions are less at 0.08% and almost same as that of diesel during in operation. Since the time available for combustion is high which results produces low $CO_2$.

From figure 5.4.4 it is observed that the HC emissions for 0.08% concentration is lower and almost similar to diesel, when compare to all other concentrations of tamarind oil. This is due to complete combustion of fuel.

## CONCLUSIONS

The experiment is carried out on a single cylinder four stroke diesel engine using of Tamarind Seed biodiesel oil as a fuel. In this experimental study the various performance parameters are observed by varying the load at different conditions in operation. The following observations are drawn from the experiment.

- Brake thermal efficiency of tamarind oil at full load condition is 43.37% which is 2.07% higher than the diesel, due to sufficient time for combustion.
- In tamarind oil for 0.06% concentration, Fuel Consumption is low compared to other concentrations, due to the viscosity of tamarind oil is more therefore at higher pressure proper atomization takes place results in low fuel consumed for the rated power. At this position lesser fuel consumed for the rated power output compared to diesel is 0.421 (Kg/ Kw.hr).
- Mechanical efficiency of tamarind oil for 0.06% concentration at full load condition is 85.80% as compare to the diesel is 86.51%. From this the 0.06% sample is almost similar to that of diesel fuel, due to sufficient time for combustion.
- Emissions of Carbon monoxide are found increased with increase in Load. At 0.06% concentration the CO emissions produced 13% less than the diesel, this is due to increasing the pressures and loads the CO emissions are reduced due to proper atomization of fuel.
- At 0.08% concentration, $CO_2$ emissions produced are almost similar to that of diesel which is at 7.3 (% volume). Since the time available for combustion is sufficient which results produces low $CO_2$.
- It is recorded that $NO_X$ emissions at 0.08% concentration 30% less compared to diesel. $NO_X$ emissions increased with increasing load.

- HC emissions at 0.08% concentration just 5% high compared to 27° diesel, which is significantly low. This is because due to complete combustion in the cylinder.

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