The Experimental Investigation On Performance And Emission Characteristic Of VCR Engine Fuelled By Waste Plastic Oil Blends With And Without Additive

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Abstract: Depleting amount of standard fuel has been focused as a larger drawback currently. Day by day, amount of petroleum, fossil oil has additional activity and lesser production. Increasing use of petrol & diesel has created the individuals of the planet to assume for a few alternative way for energy resources. At the same time. other rising drawback against the people of the planet is increase in plastic waste and utilization of the same. each of the problems square measure focused and efforts are created to induce optimum resolution. associate degree experimental setup has been ready for plastic pyrolysis oil and diesel mix to be utilized in single cylinder, 4-stroke CI engine. Plastic pyrolysis oil is obtained from plastic waste by pyrolysis method. pyrolysis method could be a thermo-chemical decomposition of organic matter in absence of element. mixing of transmutation oil with diesel helps to scale back the consumption of fuel. The variation within the mixing magnitude relation of plastic transmutation oil and fuel affects the engine performance still as exhaust emission information. to know the variation in engine performance, totally different blends of plastic transmutation oil and fuel were ready and experimentations were done by running these blends individually in engine with varied masses. Blends were ready for 100 percent, 2 hundredth and half-hour of plastic transmutation oil with ninetieth, eightieth and seventieth of fuel severally. impact of engine performance of variable compression magnitude relation diesel compared by graphical illustration of various performance parameters wppo blends with fuel

Index Terms: Plastic Pyrolysis Oil, Blend Ratio, Engine Performance, Diesel Fuel, CI Engine, Additive.

1 INTRODUCTION

Fossil fuel derived from the crude oil is one of the greatest resources known to mankind. It is the largest raw material that supports the energy systems around the world. In this era of technology and industries, energy resources are the key to survival. The exponential growth of modern society and development in the quality of life, especially for the past couple of decades, was achieved mainly by the use of petroleum products. Even though the fossil fuel will continue to dominate the energy sector in the immediate future, they are becoming limited and are depleting at high rates because of huge demand. In a developing country like India, which is the fifth highest energy consumer in the world and is a home for 1.25 billion people (17% of the world's population) and has a nominal GDP of 20.52 trillion USD (2018 estimates) the energy demand is enormous. The petroleum products play an important role in the energy production, transportation, industrial and agricultural sectors. But the crude oil reserves in India are limited and cannot reach the demand all by itself. According to the estimates in 2018, India's domestic production of crude oil meets only 25% of the demand and the remaining 75% are met by the imports. The crude oil statistics of India for the last ten years is given in Table 1.1. The local production profile is lagging far behind the consumption profile of the nation.

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As per the statistics, the dependence on the imported crude oil for the current year is above 75% and it is estimated to reach 80% by 2017-18. The country is facing a great challenge in reducing the dependency on imported oil and also it is a heavy burden on country's economy. So in order to overcome this energy crisis, the government is now implementing various important policies that will help to achieve a sustainable way of development. These initiatives are designed to reduce the dependency on crude oil imports and also for ensuring the efficient use and conservation of other conventional resources. The main idea of a sustainable model of development is to use the resources in such a way that it can meet the needs of the present generation without affecting the future generation's needs. The objectives of sustainable development essentially consider the following aspects.

- Protecting and enhancing the conventional resources
- Developing new technologies for the effective utilization of the non- conventional resources.
- Improving the quality of growth by meeting the essential needs.

The utilization of renewable energy resources is the best and safest way to achieve a clean and efficient growth and development of the nation. The renewable resources have the potential to supply energy for long term and can reduce the dependency on fossil fuels significantly. In a developing country like India, these unconventional, renewable resources offer immense possibilities. Since these resources are indigenously available in huge quantities they will reduce crude oil imports and improve the economy. Moreover, they increase the local production, which also creates a lot of job opportunities. Because of all these issues the researchers have turned their focus to find a suitable alternative energy source which can be able to meet the energy demands.

Table 1.1 *Crude oil statistics for last decade in India**

Year	*Consumption (MT)*	*Production (MT)*	*Import (MT)*
2005-2006	*130.11*	*32.19*	*99.41*
2006-2007	*146.55*	*33.99*	*111.50*
2007-2008	*156.10*	*34.12*	*121.67*
2008-2009	*160.77*	*33.51*	*132.78*
2009-2010	*192.77*	*33.69*	*159.26*
2010-2011	*196.9*	*37.68*	*163.60*
2011-2012	*204.12*	*38.09*	*171.73*
2012-2013	*219.21*	*37.86*	*189.24*
2013-2014	*222.50*	*37.79*	*189.24*
2014-2015	*223.24*	*37.46*	*189.43*
2015-2016	*232.86*	*36.94*	*202.85*
2016-2017	*244.57*	*36.00*	*213.93*
2017-2018	*251.93*	*35.68*	*220.40*

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2. METHODOLOGY

2.1 Experimental set up

An experimental set up was established in order to conduct the investigation on the direct injection, high speed light duty diesel engine. The tests were designed to estimate the performance, emission and combustion characteristics of the engine at various operating conditions. The graphic representation of the experimental setup is shown in Figure 2.1 and the photographic view of the experimental set-up is shown in Figure 2.2

The important components of the systems are:
i. The engine
ii. Dynamometer
iii. Exhaust gas analyser
iv. Data acquisition system

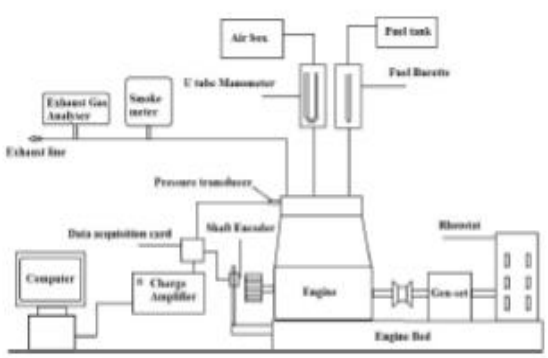

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fig 2.1 *schematic diagram of experimental setup*

Figure 3.2 *Photographic view of Test engine*

3.1.1 Test engine

A single cylinder, naturally aspirated, four stroke, water cooled DI diesel engine generating a rated power of 3.7 kW at a rated speed of 1500 RPM was used for performing the present investigation. The details of engine specifications are include. The injector opening pressure of 200bar was recommended by the manufacturer. The average of 100 cycles of pressure crank angle data was recorded to avoid variability and error. The engine was started using the diesel fuel and was then switched to plastic oil after attaining the steady state. The fuel tank was fully emptied before using a new fuel. The injection system of the engine was cleaned and calibrated after every test run. The test facility consists of the following systems and measuring instruments:

- The engine was coupled to an alternator and a rheostat, for electrical loading.
- Two separate fuel tanks for diesel and plastic oil supply. A burette and a stop watch arrangement for the flow measurements.
- An orifice plate and a U-tube manometer arrangement for air flow measurements.
- Thermocouples for measuring the temperature of exhaust gas, inlet and outlet temperature of cooling water.
- Piezoelectric transducer with charge amplifier for cylinder pressure measurements
- A high precision optical position encoder to locate TDC position.
- A digital data acquisition system and required software for acquiring and analysing the pressure crank angle data to get the combustion parameters
- Exhaust gas analyser arrangements for measuring the amount of HC, CO, CO2 and NOX in the exhaust

3.12 Exhaust Gas Analyzer

All emissions like Carbon monoxide, Carbon dioxide, Unburnt Hydrocarbons, Nitrogen oxide and unused oxygen are found in 5 gas emission analyser of model “AVL Digital gas 444” is used. In this cable, one end is connected to the inlet of the analyser and the other end is connected at the end of the exhaust gas outlet. Continuous charging of the analyser is essential to work in an effective way. Figure 3.4 shows the actual photo of Exhaust Gas Analyser attached to engine at the exit. The measuring method is based on the principle of light absorption in the infrared region, known as "non-dispersive infrared absorption

Fig: 3.3 *Exhaust gas Analyzer*

The broadband infrared radiation produced by the light source passes through a chamber filled with gas, generally methane or carbon dioxide. This gas absorbs radiation of a known wavelength and this absorption is a measure of the concentration of the gas. There is a narrow bandwidth optical filter at the end of the chamber to remove all other wavelengths before it is measured with a pyro-electric detector.

3.1.3 Data Acquisition System

The signals from the pressure pickup and TDC position sensor were acquired and stored on a computer with preinstalled software for using the digital data acquisition system. The output from the sensors was first converted from analogue to digital using an analogue to digital converter. The converter was equipped with sixteen channels which have both external and internal triggering facility. The voltage pulses from the piezoelectric transducer and encoder were given to separate channels and fed to the computer based DAS system. For each operating condition, the data for 100 consecutive cycles were recorded and the average of these cycles was taken to eliminate the fluctuations and errors in the readings. The weight averaged smoothing method was used to smooth out the curve and to eliminate any data loss during the procedure.

3.1.4 Test Procedure

In the first test, performance, emission and combustion characteristics were made by using diesel fuel. In the second test, the fuel used in the engine was 10% WPPO with 90% diesel. The third experiment was carried out by changing the fuel, containing 20% WPPO mixed with 80% diesel. The fourth experiment was completed by changing the fuel containing 30% and 80% diesel. The fifth experiment was completed by 1% DTBP, 10% WPPO with diesel. The sixth experiment was completed by changing the fuel containing 1% DTBP, 20% WPPO with diesel. The seventh experiment was completed by 1% DTBP, 30%WPPO with diesel.

- The fuel tank was filled with fuel.
- The supply of cooling water, level of lubricant in the sump of engine was checked before starting the engine. The room temperature was noted down.
- The engine was started and allowed to run at no load for about 10 minutes to warm up and attain the steady state. The engine speed was adjusted to the rated speed of 1500 rpm.
- The fuel supplied from the burette by opening the metering valve. By noting the change in the level of fuel in the burette, the time taken for 10ml of fuel consumption was noted using a stop watch.
- The desired cooling water flow rate was obtained by adjusting the valve and was kept constant throughout the experiment.
- The inlet and outlet temperatures of the cooling water were noted down. The exhaust gas temperature was noted down for different fuels.
- The load of the engine was varied from 2 kg to 12 kg. The readings were taken and tabulated for each load variation.
- The emissions such as CO, CO2, HC, NOx, were measured using the AVL gas analyser.
- All the readings were taken for various loads and fuels.

All parameters related to the engine performance were observed from the readings. After, the experimental part the calculations were carried out and various graphs were drawn. Based on the graphical analysis the conclusions have been made. For each experiment, three measurements are taken to average the data so as to determine the repeatability of the measured data and to have an estimate of measured accuracy.

3.1.5 Properties of Tested Fuel

The properties such as Gross calorific value, Density, cetane number, Flash point, Fire point oxygen content, and viscosity of diesel, waste plastic pyrolysis oil are tabulated in Table 3.1

Table 3.1 *Fuel properties of diesel, waste plastic pyrolysis oil*

Property	*Diesel*	*WPPO*
Gross calorific value (kJ/Kg)	*43,890*	*41,200*
Density @30 ºC in (g/cc)	*0.818*	*0.84 to 0.88*
Kinematic viscosity, cst@30 ºC	*2.0*	*2.52*
Cetane number	*51*	*55*
Flash point (ºC)	*50*	*42*
Fire point (ºC)	*56*	*45*

3.2 VCR ENGINE EXPERIMENTAL SET-UP

3.2.1 Experimental Test Rig

The experimental check rig consists of a variable compression quantitative relation compression ignition engine, eddy current dynamometer as loading system, fuel offer system for each fuel and wppo oil supply, water cooling system, lubrication system and numerous sensors and instruments integrated with processed information acquisition system for on-line activity of load, air and fuel rate of flow, instant cylinder pressure, injection pressure, position of crank angle, exhaust emissions and smoke opacity. The photographic image of the experimental setup employed in the laboratory to conduct this study. The schematic illustration of the experimental take a look at setup. The technical Specifications of various elements employed in the take a look at rig. The setup allows the analysis of thermal performance and emission constituents of the VCR engine.

The thermal performance parameters embody brake power, brake mean effective pressure, brake thermal potency, meter potency, brake specific fuel consumption, exhaust gas temperature, heat equivalent of brake power and warmth equivalent of exhaust gas. Commercially accessible lab read based mostly Engine Performance Analysis

3.2.2 Variable Compression Ratio (VCR) Diesel Engine.
The variable compression ratio (VCR) diesel engine used to conduct the experiments is a single cylinder, four stroke, water cooled, direct injection engine. The technical specifications of the engine are given in Table 3.2. The engine is mounted on a stationary frame with a suitable cooling system. The lubricating system is inbuilt in the engine.

3.2 Technical Specifications of VCR Diesel ENGINE

No of cylinders	*1*
No of strokes	*4*
Rated power	*3.5 kw@1500rpm*
Cylinder diameter	*87.5mm*
Stroke length	*110mm*
Stroke length	*234mm*
Compression ratio vary	*12 to 18:1*
Orifice diameter	*20mm*
Dynamometer arm length	*185mm*

3.2.3 Compression Ratio Setting
The engine with mounted compression ratio will be changed by providing further variable combustion space. There are completely different arrangements by that this will be achieved. Tilting cylinder block technique is one among the arrangements which might be used to vary the combustion space volume. A photographic image of the tilting cylinder block put in on the engine cylinder. The engine is created to operate as a variable compression ratio (VCR) engine by providing a tilting block arrangement to suitably change the compression ratio (CR) to the required price within the given range without stopping the engine and while not altering the combustion chamber geometry. The tilting engine block arrangement consists of a tilting block with six alley bolts, a compression ratio claims adjuster with lock nut and compression ratio indicator. For setting a selected compression ratio, the alley bolts area unit to be slightly loosened. Then, the lock nut on the {adjuster|adjustor|claims adjuster|claims adjustor|claim agent|investigator} is to be unsnarled and also the adjuster is to be rotated to line a selected compression ratio by referring to the compression ratio indicator and to be locked using lock nut. Finally all the Alley bolts area unit to be tightened gently. The compression ratios considered for conducting the experiment is eighteen.
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4.2 OBSERVATIONS:

4.2.1 Performance characteristics and Emission characteristics at 200 bar Injection pressure:
At 200 bar injection pressure and compression ratio(18:1) for B10 ,B20 and B30 blends with and without additive theresults such as B.P, I.P, Mechanical efficiency are obtained as follows.

Load (kg)	*IP (kW)*	*FP (kW)*	*BP (kW)*	*BTHE (%)*	*ITHE (%)*	*Mech Eff. (%)*	*Fuel consumption(cc/min)*	*Torque (Nm)*
0	*3.16*	*3.16*	*0.00*	*0.00*	*72.44*	*0.00*	*20.4*	*0.00*
3	*4.11*	*3.16*	*0.50*	*7.27*	*60.35*	*12.16*	*36*	*3.18*
6	*4.91*	*3.16*	*1.30*	*15.86*	*71.40*	*26.47*	*42.6*	*8.27*
9	*5.73*	*3.16*	*2.12*	*21.7*	*70.08*	*36.99*	*51*	*13.49*
12	*6.41*	*3.16*	*2.80*	*23.23*	*59.98*	*43.68*	*63.6*	*17.82*

Table 4.1: *calculated thermal parameters forB10 at 200 bar*

Load (kg)	*IP (kW)*	*FP (kW)*	*BP (kW)*	*BTHE (%)*	*ITHE (%)*	*Mech Eff. (%)*	*Fuel consumption(cc/min)*	*Torque (Nm)*
0	*2.9*	*2.9*	*0.00*	*0.00*	*73.24*	*0.00*	*20.84*	*0.00*
3	*3.55*	*2.9*	*0.65*	*9.78*	*77.86*	*18.30*	*34.99*	*4.13*
6	*4.25*	*2.9*	*1.35*	*16.23*	*72.25*	*31.76*	*43.8*	*8.59*
9	*5.2*	*2.9*	*2.3*	*23.30*	*70.13*	*44.23*	*51.96*	*14.04*
12	*5.7*	*2.9*	*2.8*	*24.59*	*54.98*	*49.12*	*70.20*	*17.86*

Table 4.2: *calculated thermal parameters for B20 at 200 bar*

Load (kg)	*IP (kW)*	*FP (kW)*	*BP (kW)*	*BTHE (%)*	*ITHE (%)*	*Mech Eff. (%)*	*Fuel consumption(cc/min)*	*Torque (Nm)*
0	*2.7*	*2.7*	*0.00*	*0.00*	*70.42*	*0.00*	*20.1*	*0.00*
3	*3.39*	*2.7*	*0.69*	*10.77*	*82.31*	*20.35*	*35.40*	*4.39*
6	*4.2*	*2.7*	*1.5*	*18.06*	*76.96*	*35.71*	*41.69*	*9.54*
9	*5.08*	*2.7*	*2.38*	*24.43*	*71.96*	*46.85*	*51.06*	*15.15*
12	*5.7*	*2.7*	*3*	*25.59*	*62.60*	*52.63*	*61.20*	*19.09*

Table 4.3: *calculated thermal parameters for B30 at 200 bar*

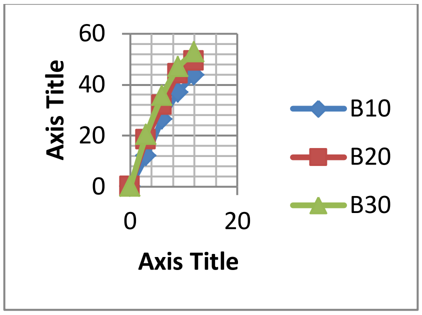

fig4.2: *Load vs. Mechanical efficiency at 200 bar for all blends without additive*

In this i have compared Load in kg on x-axis and Mechanical efficiency on y-axis. As we know that when we increase load the brake power gets increased i.e. the useful power at the rear wheel and mechanical efficiency also gets increased because it is directly proportional to brake power. Mechanical efficiency increases gradually from no load to peak load, but B30blend without additive having higher mechanical efficiency is 52.63%.In this i have compared Load in kg on x-axis and Fuel consumption in cc/min on y-axis. As we know that when we increase load the brake power gets increased i.e. the useful power at the rear wheel. At low load we get fuel consumption less because brake power is inversely proportional to fuel consumption rate. At lower loads fuel consumption of all blends are low but B20 blend having higher fuel consumption is 70.20cc/min.

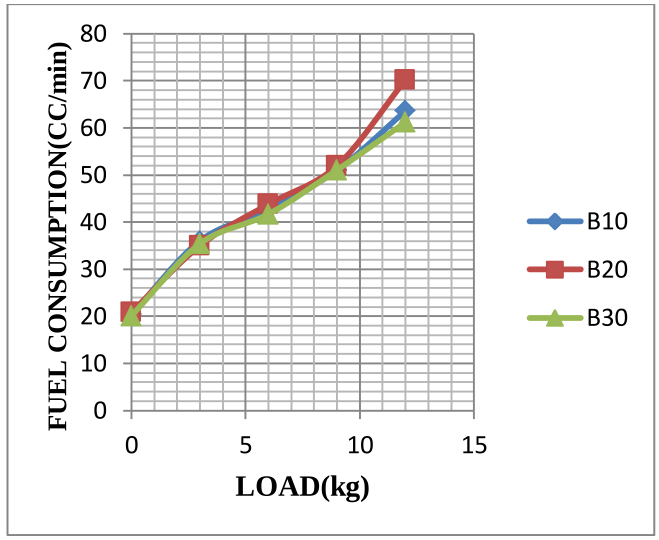

Fig4.3: *Load vs Fuel consumption(cc/min) at 200 bar for all blends without additive*

Load (kg)	*IP (kW)*	*FP (kW)*	*BP (kW)*	*BTHE (%)*	*ITHE (%)*	*Mech Eff. (%)*	*Fuel consumption(cc/ min)*	*Torque (Nm)*
0	*3.2*	*3.2*	*0.00*	*0.00*	*77*	*0.00*	*19.92*	*0.00*
3	*3.72*	*3.2*	*0.52*	*8.20*	*65.49*	*13.97*	*31.68*	*3.30*
6	*4.52*	*3.2*	*1.32*	*17.18*	*76.40*	*29.20*	*42*	*8.40*
9	*5.33*	*3.2*	*2.13*	*22.64*	*72.82*	*39.96*	*51.6*	*13.56*
12	*6.02*	*3.2*	*2.82*	*25.27*	*65.40*	*46.84*	*61.80*	*17.95*

Table 4.4: *calculated thermal parameters for B10 with additive at 200 bar*

Load (kg)	*IP (kW)*	*FP (kW)*	*BP (kW)*	*BTHE (%)*	*ITHE (%)*	*Mech Eff. (%)*	*Fuel consumption(cc/ min)*	*Torque (Nm)*
0	*2.98*	*2.98*	*0.00*	*0.00*	*79.5*	*0.00*	*19.62*	*0.00*
3	*3.88*	*2.98*	*0.90*	*14.10*	*84*	*23.19*	*35.16*	*5.72*
6	*4.58*	*2.98*	*1.6*	*20.73*	*77.9*	*34.93*	*42.54*	*10.18*
9	*5.28*	*2.98*	*2.30*	*24.48*	*74.8*	*43.56*	*48.18*	*14.64*
12	*5.91*	*2.98*	*2.93*	*24.14*	*61.13*	*49.57*	*66.6*	*18.65*

Table 4.5: *calculated thermal parameters for B20 with additive at 200 bar*

Load (kg)	*IP (kW)*	*FP (kW)*	*BP (kW)*	*BTHE (%)*	*ITHE (%)*	*Mech Eff. (%)*	*Fuel consumption(cc/ min)*	*Torque (Nm)*
0	*2.7*	*2.7*	*0.00*	*0.00*	*79.52*	*0.00*	*18.54*	*0.00*
3	*3.62*	*2.7*	*0.92*	*13.27*	*78.20*	*25.41*	*37.14*	*5.72*
6	*4.33*	*2.7*	*1.63*	*21.20*	*76.54*	*37.64*	*40.80*	*11.02*
9	*5.05*	*2.7*	*2.35*	*25.23*	*77.42*	*46.53*	*51*	*14.96*
12	*5.7*	*2.7*	*3*	*25.44*	*63.09*	*52.63*	*64.56*	*19.09*

Table 4.6*: calculated thermal parameters for B30 with additive at 200 bar*

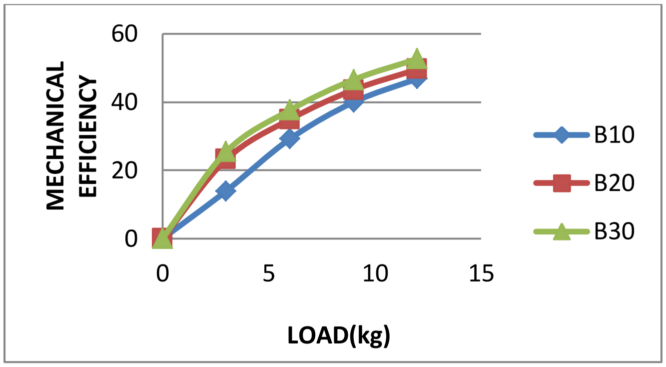

Fig4.4: *Load vs. Mechanical efficiency at 200 bar for all blends with additive*

In this i have compared Load in kg on x-axis and Mechanical efficiency on y-axis. As we know that when i increase load the brake power gets increased i.e. the useful power at the rear wheel and mechanical efficiency also gets increased because it is directly proportional to brake power. Mechanical efficiency increases gradually from no load to peak load, but B30blend without additive having higher mechanical efficiency is52.63 %.In this case both B20&B30 mechanical efficiencies are nearly equal.

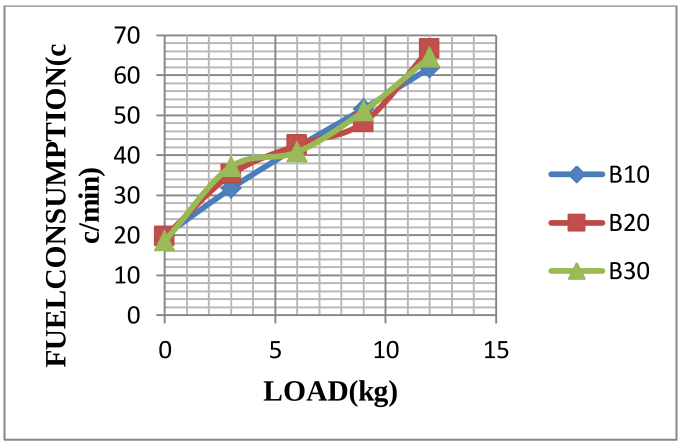

Fig4.5: *Load vs. Fuel consumption (cc/min) at 200 bar for all blends with additive*

In this i have compared Load in kg on x-axis and Fuel consumption in cc/min on y-axis. As we know that when we increase load the brake power gets increased i.e. the useful power at the rear wheel. At low load we get fuel consumption less because brake power is inversely proportional to fuel consumption rate. By the addition of additive to the blends increases the fuel consumption and B10 fuel consumption increases gradually but B20&B30 blends of fuel consumption increases at lower loads and decrease at 6kg load later increases upto peak load. In this case higher fuel consumption is B20 blend is66.6cc/min.
Comparing the above two cases such as with and without an additive, mechanical efficiency is not changed but fuel consumption is decreased at B20 blend with additive.

Emission characteristics at 200 bar Injection Pressure:
At 200 bar injection pressure the emissions like CO, CO_2, NOx, HC emissions were observed how they are varying according to load with and without additive.

CO Emissions at 200 bar (without additive):

CO EMISSIONS(%) FOR VARIOUS BLENDS AT 200 BAR				
LOAD(kg)	*B10*	*B20*	*B30*	*DIESEL*
0	*0.064*	*0.064*	*0.060*	*0.065*
3	*0.045*	*0.042*	*0.038*	*0.048*
6	*0.038*	*0.038*	*0.035*	*0.042*
9	*0.024*	*0.026*	*0.024*	*0.025*
12	*0.02*	*0.01*	*0.027*	*0.01*

Table4.7: *CO emissions for various blends at 200bar Injection pressure*

CO Emissions at 200 bar with additive:

CO EMISSIONS(%) FOR VARIOUS BLENDS AT 200 BAR				
LOAD(kg)	*B10*	*B20*	*B30*	*DIESEL*
0	*0.060*	*0.059*	*0.056*	*0.065*
3	*0.039*	*0.030*	*0.028*	*0.048*
6	*0.030*	*0.028*	*0.026*	*0.042*
9	*0.020*	*0.019*	*0.019*	*0.025*
12	*0.02*	*0.01*	*0.01*	*0.01*

Table4.8: *CO emissions for various blends at 200bar Injection pressure*

From the tables 4.7 & 4.8 i observed that increase in load decreases CO emissions gradually both the cases but with addition of additive to the blends the CO emissions at peak loads equal to diesel.

CO_2 Emissions at 200 bar(without additive):

CO_2 EMISSIONS(%) FOR VARIOUS BLENDS AT 200 BAR				
LOAD(kg)	*B10*	*B20*	*B30*	*DIESEL*
0	*1.3*	*1.3*	*1.3*	*1.3*
3	*1.52*	*1.6*	*1.56*	*1.62*
6	*1.93*	*1.86*	*1.8*	*2.1*
9	*2.03*	*2.08*	*2.0*	*2.14*
12	*1.93*	*2.02*	*2.2*	*1.96*

Table4.9: *CO_2 emissions for various blends at 200bar Injection pressure*

CO_2 Emissions at 200 bar with additive:

CO_2 EMISSIONS(%) FOR VARIOUS BLENDS AT 200 BAR				
LOAD(kg)	*B10*	*B20*	*B30*	*DIESEL*
0	*1.28*	*1.27*	*1.27*	*1.3*

3	1.50	1.52	1.52	1.62
6	1.79	1.67	1.65	2.1
9	1.98	1.80	1.82	2.14
12	1.80	1.78	1.83	1.96

Table4.10: *CO2 emissions for various blends at 200bar Injection pressure*

From the tables 4.9& 4.10 i observed that CO_2 emissions increases with increase in load at all blends in both the cases. But CO2 emissions decreases with addition of additive compare to diesel ,the lowest CO2 emission is B20 blend with additive.

HC (ppm) Emissions at 200 bar(without additive):

HC EMISSIONS FOR VARIOUS BLENDS AT 200 BAR				
LOAD(kg)	B10	B20	B30	DIESEL
0	40	44	49	41
3	37	40	45	34
6	35	36.5	43	27
9	33	35	40	24
12	30	34	39	22

Table4.11: *HC emissions for various blends at 200bar Injection pressure.*

HC (ppm) Emissions at 200 bar with additive:

HC EMISSIONS FOR VARIOUS BLENDS AT 200 BAR				
LOAD(kg)	B10	B20	B30	DIESEL
0	38	36	36	41
3	35	33	32	34
6	32	30	30	27
9	31.5	29	28	24
12	30	28	27	22

Table4.12: *HC emissions for various blends at 200bar Injection pressure.*

From the tables 4.11&4.12 reveals that HC emissions increases both the cases from no load to peak load for all blends moreover higher than the diesel values, because of un-burned fuel is more in increase in load.

NO_X (ppm) Emissions at 200 bar(without additive):

NO_X EMISSIONSFOR VARIOUS BLENDS AT 200 BAR				
LOAD(kg)	B10	B20	B30	DIESEL
0	117	130	110	105
3	210	215	170	180
6	350	350	270	340
9	430	480	370	380
12	450	510	500	430

Table4.13: *NO_X emissions for various blends at 200bar Injection pressure*

NO_X (ppm) Emissions at 200 bar with additive:

NO_X EMISSIONS FOR VARIOUS BLENDS AT 200 BAR				
LOAD(kg)	B10	B20	B30	DIESEL
0	109	98	100	105
3	190	175	190	180
6	320	320	260	340
9	350	360	330	380
12	430	400	400	430

Table4.14: *NO_X emissions for various blends at 200bar Injection pressure*

From the tables 4.13&4.14 i observed that increases the NO_X emissions with increase in load both the cases because of un- burnt fuel but with addition of additive to blends at peak load decreases and equal to diesel values of NO_X

5.0 RESULTS AND DISCUSSIONS

In this chapter, engine performance, emission and combustion characteristics test results have been presented with the help of detailed graphs. The first experiment was conducted in a standard diesel engine at an engine speed of 1500rpm. A comparison of the engine performance, the emission and the combustion characteristics for the following combinations, made and the results presented.

- Diesel
- Waste plastic pyrolysis oil blends with diesel
- Waste plastic pyrolysis oil blends with diesel with DTBP additive

The following codes are used for diesel, waste plastic pyrolysis oil and diethyl ether mixed waste plastic pyrolysis oil as they provide ease for the graphical illustration of the experimental data.

Diesel...: DE
Waste plastic pyrolysis oil ....: WPPO
Waste plastic pyrolysis oil 10% + 90% Diesel ....: WD10%
Waste plastic pyrolysis oil 20% + 80% Diesel ....: WD20%
Waste plastic pyrolysis oil 30% + 70% Diesel ....: WD30%
Waste plastic pyrolysis oil 10% + 90% Diesel +1%DTB: WD10%

Waste plastic pyrolysis oil 20% + 80% Diesel +1%DTBP..... :WD20%
Waste plastic pyrolysis oil 30% + 70% Diesel +1%DTBP......: WD30%

5.1.1 Brake power

Figures 5.1 and 5.2 show the variation of brake power with respect load applied. It indicates that the Brake power increases with increase in load, which is due to increase in amount of fuel to maintain the constant RPM corresponding to load increase These figures conclude that blending of waste plastic oil (with and without additive) with pure diesel. But compare to without additive blend values of wppo, D90 B20 with additive values are very close trend with pure diesel corresponding to variation of load. Figures also indicate that plastic oil is safer to save the30% diesel without loss of power at compression ratio18:1

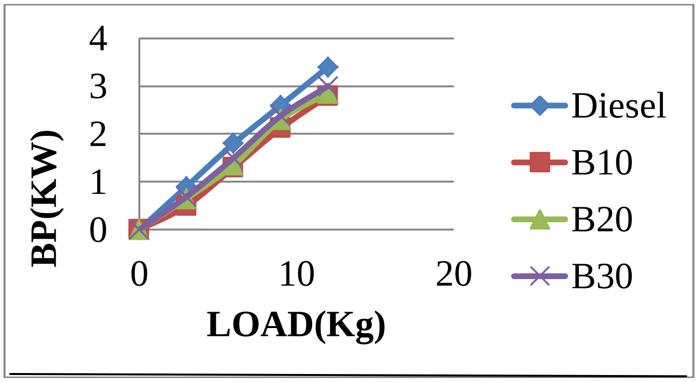

Figure 5.1 *Variation of brake power with Load and blends without additive*

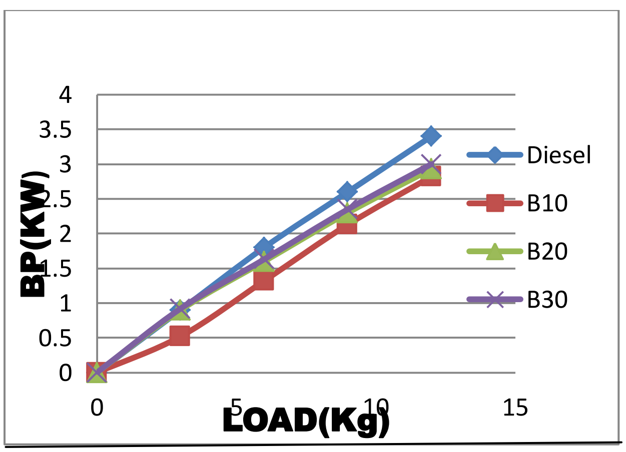

Figure 5.2 *Variation of brake power with load applied and blends with additive*

5.1.2 Brake thermal efficiency

Brake thermal efficiency (BTE) signifies how efficiently engine is capable to convert fuel into mechanical energy. Figures 5.1and 5.2 illustrate the graph between the brake thermal efficiency and load applied from no load to full load. It shows that the variation of brake thermal efficiency with compression ratio of 18:1. The brake thermal efficiency tends to be the same at lower loads. Brake thermal efficiency (BTE) increases with respect to increase in load, compression ratio, blending ratio up to 30%, and for all blend. However, the gap of BTE of diesel and blended fuels are different. Figure 5.1 shows maximum BTE at full load for diesel, B10,B20and B30 without additive are 20.82% and 23.23%,24.59% and 25.59% respectively at CR18. Figure 5.2 shows that at maximum load BTE for diesel and B10,B20 and B30 with additive are 20.82%, 25.27%, 24.14% and25.44% correspondingly at CR 18.By comparing BTE with and without additive with diesel ,it is clearly reveals that BTE of wppo values at peak load higher than the diesel in both the cases. Brake thermal efficiency increased by 4.62%.The above results shows that this is an alternate fuel for diesel because raw materials of waste plastics are petroleum products. Higher thermal efficiencies of Blended fuel than the diesel fuel is because of lesser fuel consumption in case of blended fuel. Similarly, with increase in blend proportions, fuel consumption is consistently decreasing. So, thermal efficiency is increasing with increase in blend proportion of plastic pyrolysis oil in diesel fuel.

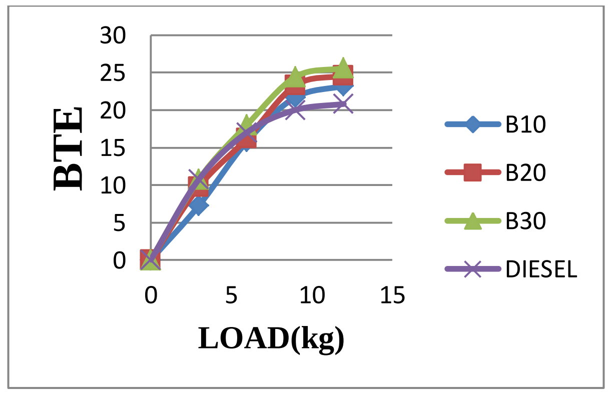

Figure 5.3 *Variation of brake thermal efficiency with Load and blends without additive*

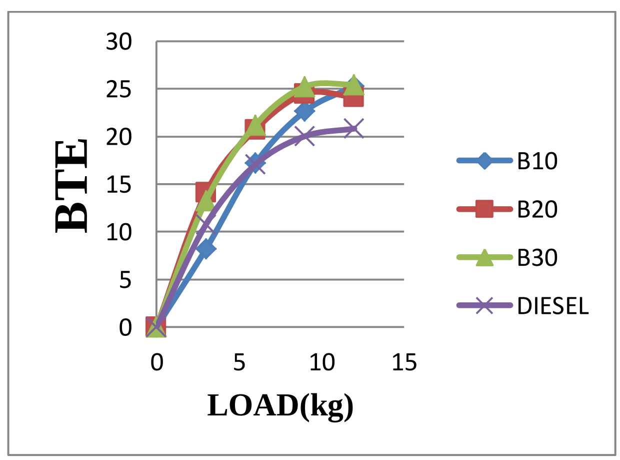

Figure 5.3 *Variation of brake thermal efficiency with Load and blends with additive*

5.1.3 Mechanical efficiency

Fig 5.5 focuses on the variation of Mechanical Efficiency with loads for various Fuel and Blend Proportions. Mechanical Efficiency increases gradually with increase in loads. At lower loads, mechanical efficiency is minimum and at full load condition, we get maximum mechanical efficiency. Comparing, the efficiency of diesel and WPPO

Blends with and without additive, we get maximum Mechanical Efficiency for WPPO blends in both the cases than diesel at peak load . Increasing Blending ratio from 10% to 30%, gives positive impact on Mechanical Efficiency as it seems increasing. The comparison of Mechanical Efficiency for Different Fuel and Blends at different loads is easily visible and understood from the figures.

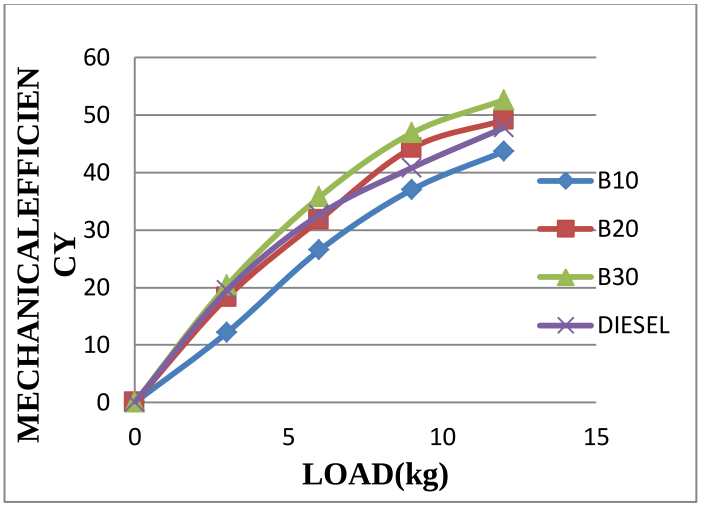

Fig 5.5 *Mechanical Efficiency vs Load for various Blend Proportions without additive*

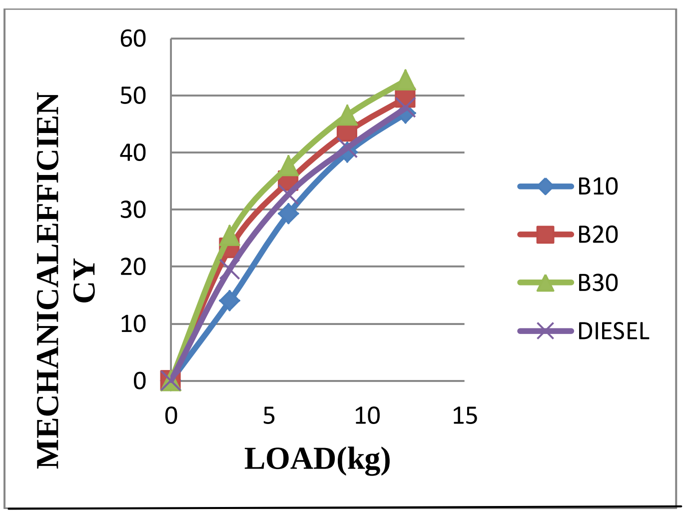

Fig:5.6 *Mechanical Efficiency vs Load for various Blend Proportions with additive*

5.1.4 Fuel consumption

Fig: 5.7 and 5.8 shows that the variation of Fuel Consumption with Engine loads for various blend proportions in the diesel Fuel. From the figures, we can analyse the variation of Fuel Consumption with varying load. As load increases, fuel consumption increases. Plastic Pyrolysis Oil is added as a blended fuel in proportion of 10%, 20% and 30% with diesel Fuel. It is clearly seen from the graph that fuel consumption in 20% Blend i.e. P20D80 Fuel, is quite similar to Diesel fuel. Fuel consumption in 10% Blend is nearer to Diesel fuel for medium loads, the same is lower than diesel fuel. For lower to medium loads, Fuel Consumption is higher for 20% Blend than in 30% Blend and the same repeats for 10% Blend than 20% Blend. So, Fuel consumption increases with decrease in blend proportions and it seems minimum for 30% Blend proportion i.e. for D70B30 Fuel. This can be due to gradually increasing calorific value with the increase in blend ration of plastic pyrolysis oil. More heat release will be there with more calorific value and thus lesser fuel is consumed with increase in blend percentage of plastic pyrolysis oil. By adding additive to WPPO the fuel consumption is low in D80B20 because of cetane number improver

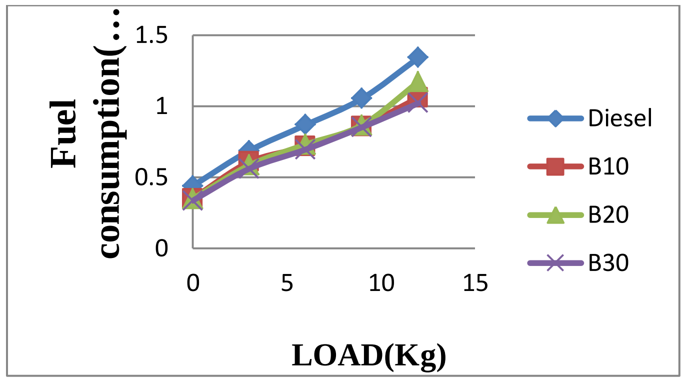

Fig 5.7*: Fuel consumption vs loads with blends without additive*

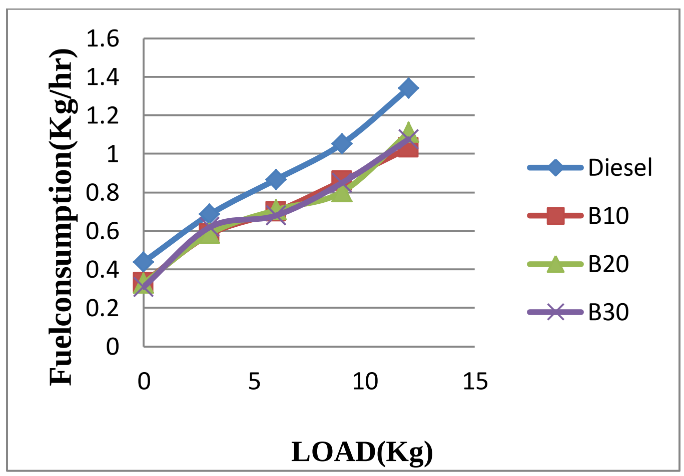

Fig 5.8: *fuel consumption vs load with blends with additive*

5.1.5 Break specific fuel consumption

Figures 5.9 and 5.10 represents about the variation of brake specific fuel consumption (BSFC) with respect to different loads applied in kg up to full load equivalent to no load - full load, and compression ratio of 18:1. These graphs prove that as the load increases, BSFC decreases continuously for all blendes with corresponding compression ratio. This is because, when the load increases temperature inside the cylinder increases, reduces delay period, total combustion timing increases and result proper combustion of fuel. It can also be noticed that trend of falling BSFC corresponding to load applied is almost same for pure diesel and B20 and B30 blends with and without an additive, however it differs for lesser ratio of blend and lower load. The variation in BSFC at maximum load for diesel and B30 is 0.40, 0.38 kg/kWh without additive moreover with additive the BSFC at full load compare to diesel with all blends the values are 0.40, 0.37, 0.38, and 0.38 kg/kWh respectively. These trends of BSFC is all because of possessing high calorific value of WPO and better combustion toward higher compression ratio.

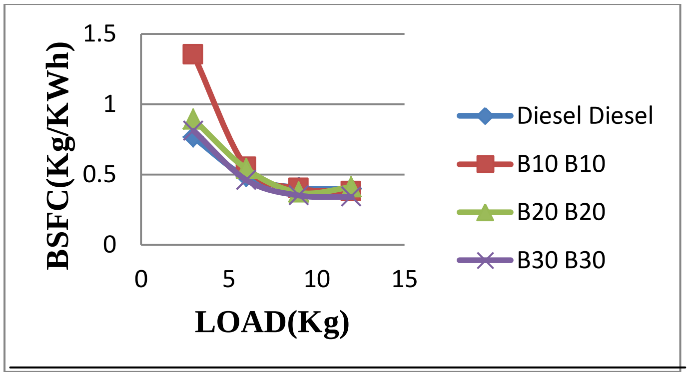

***Fig 5.9**: BSFC vs Load with blends without additive*

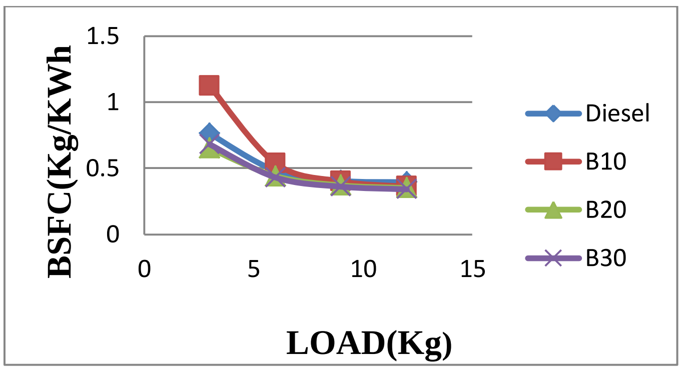

***Fig 5.10:** BSFC vs Load with blends with additive*

5.1.6 TORQUE

Torque is one of the critical measurements, especially for the development of combustion engines and transmission. Figures 5.11 and 5.12 depicts that torque of diesel values are higher compare to blends with and without additive .But torque increases from no load full load at compression ratio18. Moreover torque values of D90B20 and D80B30and D70B30 without additive are lower than diesel values at all loads. But with the adding of DTBP additive to wppo blends increases the torque for all blends, but D70B30 torque are equal to diesel at lower loads. It is clearly depicts that increase torque it means increase the break power.

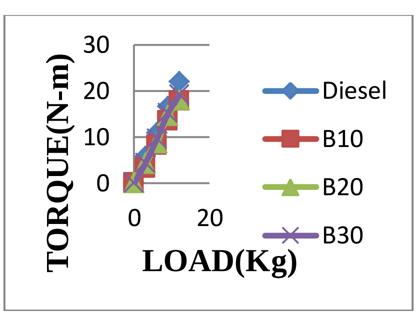

***Fig 5.11:** Torque vs load with blends without additive*

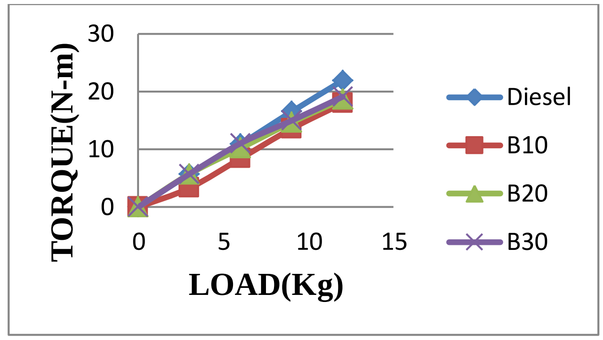

***Fig 5.12:** torque vs load with blends with additive*

5.2 EXHAUST GAS EMISSION ANALYSIS

5.2.1 CO emissions

A toxic gas Carbon monoxide (CO) emitted from the engine, measured at tail pipe corresponding to variation of load, and at compression ratio of 18 are shown in the figures 5.13and 5.14 respectively. The CO produced during the combustion due to lack of oxygen, poor air entrapped, mixture preparation and incomplete combustion. It observed that Carbon monoxide (CO) decreases with increase in load, but at maximum load waste plastic oil blends with and without additive values of CO emissions are higher than diesel. CO emissions decreases continuously for all blendes at lower loads, and the value of emission in volume percentage for B30 and pure diesel(without additive) at maximum load are0.01 and 0.03, and with additive at full load the values are 0.01 and 0.02 at compression ratio 18 respectively. The reason behind decreased CO emission may be due to increase in combustion efficiency and better mixing. It can be noticed that the decreased in the value of CO emission with increase in load, blending ratio, and compression ratio.

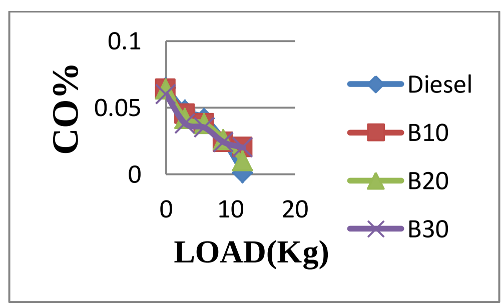

Fig 5.13: CO vs Load with blends without additive

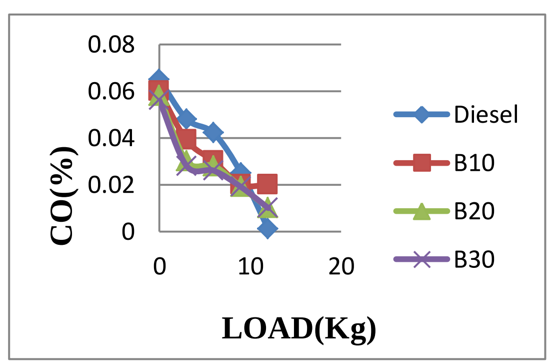

***Fig 5.14:** CO vs Load with blends with additive*

5.2.2 CO_2 emissions

Increasing tendency of CO_2 emission corresponds to the complete combustion, however CO emission shows incomplete combustion. CO_2 emission decreases corresponding to increasing thermal efficiency. CO_2 exhaust emission measured at exhaust tail at different blends with and without additive (B10, B20, B30) and compression ratio 18 with respect to loads. CO_2 emissions increases gradually from no load peak load, but at peak load without additive of WPPO values are equal to diesel. With adding of DTBP to waste plastic oil decreases CO_2 emissions at all blends. D70B30 without additive value is more at peak load.

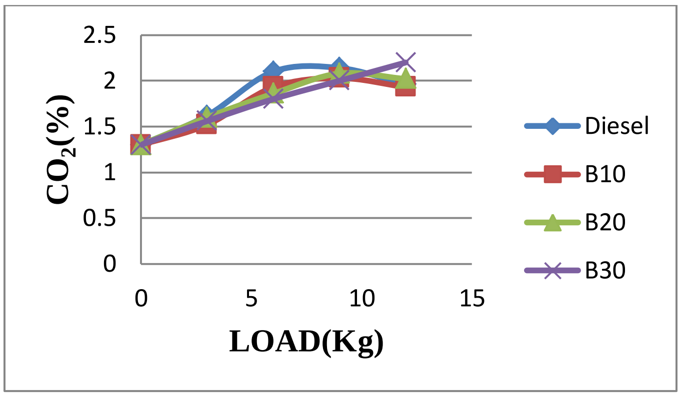

Fig 5.15: *CO_2 vs Load with blends without additive*

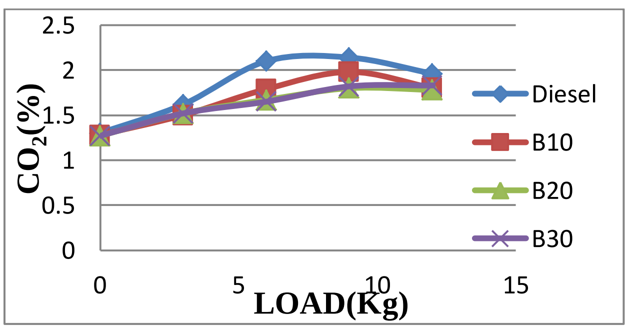

Fig 5.16: *CO_2 vs Load with blends with additive*

5.2.3 Hydrocarbons

Fig. 5.17 and 5.18 emphasises on variation of HC with load for Different Blend Proportions. From the graphs of Emissions vs Load, we can conclude that HC Emissions are significantly lower with Diesel Fuel than the Blends of Plastic Pyrolysis Oil. At all the loading conditions, HC Emissions are increasing with increase in blend proportions. But there is a major increase in this emission 30% blend of plastic pyrolysis oil. This may be due to less volatility of plastic pyrolysis oil. HC content of the fuel are not equally distributed in the cylinder area and thus some particles remains unburned which creates higher HC Emissions in without additive blend but with additive decrease HC emissions below the diesel values because of high cetane number improver of additive.

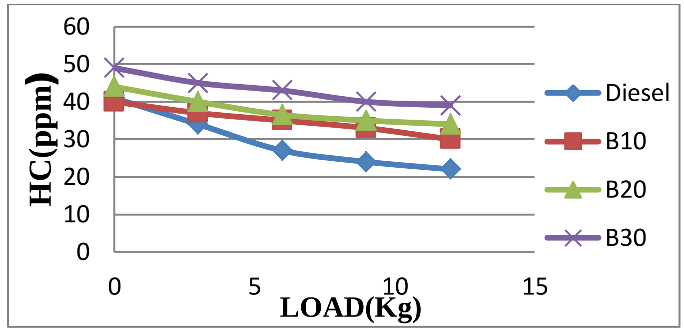

Fig 5.17 *HC vs Load with blends without additive*

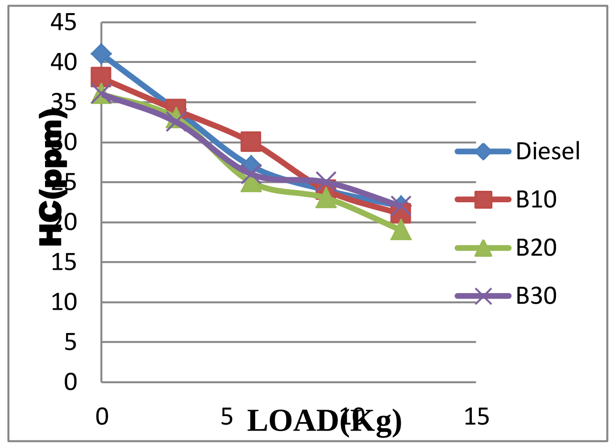

Fig 5.18: *HC vs Load with blends with additive*

5.2.4 NO_x emissions

NO_x emission at the exhaust tail of an engine have been measured in parts per million (ppm) for different blends of WPO (with and without additive) with pure diesel and with the compression ratio 18. The reason of NO_x formation is mainly due to availability of oxygen, reaction time and higher temperature during combustion. NO_X Emissions are increasing with increase in blend proportion and value becomes much higher compare to diesel. But with addition of additive to blends decreases NOx emissions. Figure 5.20 show that at maximum load NOx emission for diesel and B30 is 430ppm and 400 ppm respectively for CR 18

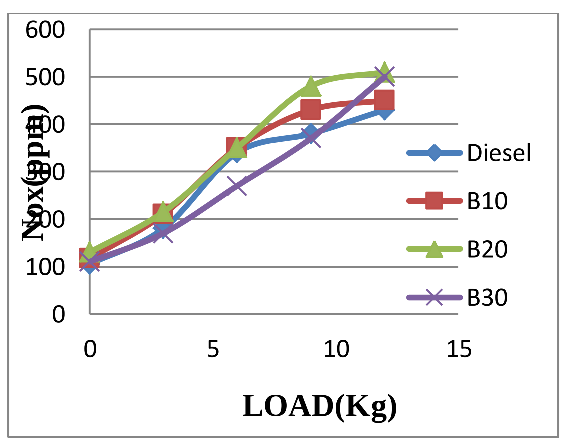

Fig : 5.19 *NOx vs Load with blends without additive*

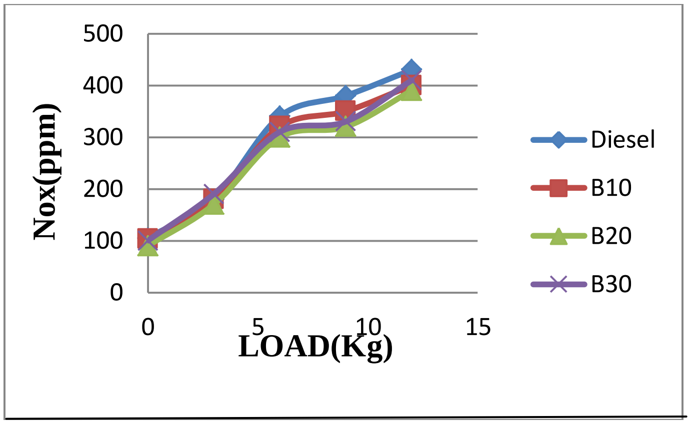

Fig 5.20: *NOx vs Load with blends with additive*

The engine performance, exhaust emission and combustion characteristics of diesel, waste plastic pyrolysis oil, waste plastic pyrolysis oil with di tert butyle peroxide(additive) blends (WD10, WD20,WD30) were experimentally investigated in a diesel engine. The engine performance and emission characteristics of a variable compression ratio engine working with fuel as diesel, waste plastic pyrolysis oil, waste plastic pyrolysis oil-di tert butyle peroxide (additive) blends were investigated. The following conclusions have been drawn based on the experimental results.

6 CONCLUSION ON EXPERIMENTAL INVESTIGATION

WPPO blends without DTBP additive

Break power increases with increase in blends at no load to full load. Break thermal efficiency increases slightly with increase in load, maximum BTE obtained in D70B30 blend. BSFC for different fuels shows decline with increase in load. Mechanical efficiencies increases with increase in load, higher mechanical efficiency gained D70B30 blend is 52.63%.The Torque values of WPPO blend increases with load, but lower than diesel and D70B30 values are nearer to diesel. The CO emission decreases with increase WPPO blend compared with DIESEL. But at full load the D70B30 of CO value is higher than diesel. The CO2 emission increases with increase in load. HC emission increases with increasing WPPO blend ratio than the Diesel. NOx emission increases with increase in load, but at D70B30 values of NOx emissions are lower than diesel up to 9 kg load.

WPPO blends with DTBP additive

i. Break power increases with increase in load but lower than diesel. But B20 and B30 blend values are same at 3kg load because of additive adding to WPPO oil.

ii..Break thermal efficiency with increase in load. Moreover break thermal efficiency values of B10&B30 are higher than diesel at 3kg load. In addition to that compare to other blends B30with additive having higher break thermal efficiency at full load. By adding additive to WPPO the break thermal increased by 4.6% respectively.

iii. Mechanical efficiency increases gradually from no load to full load for all blends but these values are higher than diesel. But at peak loads of B20& B30 values of mechanical efficiency values are 49.57% and52.63% respectively.

iv. BSFC of blends of WPPO with additive decreases with increase in load, but B20&B30 blends WPPO fuel consumption lower than diesel from zero load to full load because of additive adding to the wppo.

v. The CO emission of WPPO blends with additive decreases at lower loads compare to diesel but increases at full load condition.

vi. CO_2 emission increases with increase in load but values of CO_2 emission compare to diesel lower at each blend. B10 blend of wppo of CO values are nearer to diesel.

vii. HC emission of wppo with additive values lower than diesel with increase in load except B10 blend because of cetane number improver of DTBP additive.

viii. NOx emission of WPPO blends with additive values is lower than diesel from no load to full load condition for all blends. Because of the cetane number improver of DTBP.

Finally, the experimental study suggested that the addition of 1% DTBP by volume to waste plastic oil blend has the best alternate fuel to improve the performance and emission characteristics of conventional diesel engine without any modification.

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