Performance and Emission Characteristics of Tire Pyrolysis Oil (TPO) Blend with Diesel for Various composition

Pawan A R [1], Nagesh P V[1], Dilli ram kandel[1], Manish kumar [1]
Mohan Kumar G R[2], Arvind V Aditya[3]

[1]UG Students, Department of Automobile Engineering, New Horizon College of Engineering, Bangalore, India
[2] Assistant Professor, Department of Automobile Engineering, New Horizon College of Engineering, Bangalore, India
[3] Lecturer, Department of Mechanical Engineering, Ramaiah polytechnic, Bangalore, India

---***---

Abstract - *Due to the fossil fuel disaster in past decade, mankind has to spotlight on emergent the alternate energy sources such as biomass, hydropower, geothermal energy, wind energy, solar energy, and nuclear energy. The rising of alternative-fuel technologies are examined to convey the alternate of fossil fuel. The focused technologies are bio-ethanol, bio-diesel lipid derived biofuel, waste oil recycling, pyrolysis, gasification, dimethyl ether, and biogas. On the other hand, suitable waste management tactic is another important feature of sustainable development since waste problem is troubled in every city. To meet the growing fuel requirements many governments are entering into biodiesel sector and some private corporations are also performance more interest in this field. in addition research is going on practical suitability of Tyre Pyrolysis oil in various applications. This paper is concerned with groundwork of blends with Tyre Pyrolysis oil. The load test is conducted on IC engine at constant speed with different blend compositions of Tyre Pyrolysis oil and diesel and performance curves are planed.*

Key Words: Tire pyrolysis oil, blends, performance, diesel engine, emission characteristics.

1. INTRODUCTION

Due to the fossil fuel crisis in past decade, mankind has to focus on developing the alternate energy sources such as biomass, hydropower, geothermal energy, wind energy, solar energy, and nuclear energy. The developing of alternative-fuel technologies are investigated to deliver the replacement of fossil fuel. The focused technologies are bio-ethanol, bio-diesel lipid derived bio-fuel, waste oil recycling, pyrolysis, gasification, di-methyl ether, and biogas. On the further, appropriate waste management approach is another important aspect of sustainable development since waste problem is concerned in every city.

The waste to energy technology is investigated to process the prospective materials in waste which are tire, biomass and plastic to be oil. Pyrolysis process becomes an option of waste-to-energy technology to distribute bio-fuel to replace fossil fuel. Waste tire and waste plastic are investigated in this research as they are the accessible technology. The advantage of the pyrolysis process is its ability to handle unsorted and dirty plastic. The pre-treatment of the material is easy. Tire is needed to be shredded while plastic is needed to be sorted and dried. Pyrolysis is also no toxic or environmental harmful emission unlike incineration

The tire pyrolysis oil and plastic pyrolysis oil have been investigated and found that they both are able to run in diesel engine and the fuel properties of the oils are comparable to diesel oil. Both pyrolysis oils are a complex mixture of emission characteristics have made it popular in small automobile engines for passenger cars and light trucks.

However there is an urgent need to address the problems of depleting of fossil fuels source and increased greenhouse gas emissions. India spends huge resaves of foreign exchange every year for importing crude and petroleum products. Petroleum fuels resources are limited. Need for search of alternate fuels to meet future demand is continuous process since interception of I.C engines.

Diesel/Gas oil is one of the derivatives of fossil fuel used in the transportation sector. In India, diesel fuel consumption constitutes about 49% of the petroleum products utilized in the country. Consumption has been growing steadily at an annual rate of about 5%. Diesel can thus be seen as an important derivate of fossil fuel to the economy. Aside the transportation sector, the mining sector is also heavily reliant on diesel accounting for about 10% of the total consumption in the country. Replacing petroleum derived diesel with alternative sources will have a huge positive impact on the quantity of fossil fuels imported into the country and thus conserve the nation's foreign currency reserves. Aside this, an added advantage of pursing a bio-fuel policy is its ability to create and sustain jobs especially in the agriculture sector of the economy.

The use of Tire pyrolysis oil as a substitution to diesel fuel is an opportunity in minimizing the utilization of the natural resources. Several research works have been carried out on the pyrolysis of waste automobile tires. Pyrolysis is the process of thermally degrading a substance into smaller, less complex molecules. Pyrolysis produces three principal products: such as pyrolytic oil, gas and char. The quality and quantity of these products depend upon the reactor temperature and design. In the Pyrolysis process, larger hydrocarbon chains break down at certain temperatures in the absence of oxygen that gives end products usually containing solids, liquids and gases. If the temperature is maintained at 550^0C, the main product is a liquid, which could be a mixture of various hydrocarbons depending on the initial composition of the waste material. At temperatures above 700^0C, the gas becomes the primary product due to further cracking of liquids. The gas is basically composed of CH4, with C2H6, C2H4, C2H2, and other gaseous hydrocarbons however in lesser quantities. The quality and quantity of these products depend upon the reactor temperature and design. In the present work pyrolysis oil from waste tires by vacuum pyrolysis is obtained. Though solid carbon black and pyrolysis gas are also obtained, the pyrolysis process will be much more prominent to produce liquid.

2. METHODOLOGY

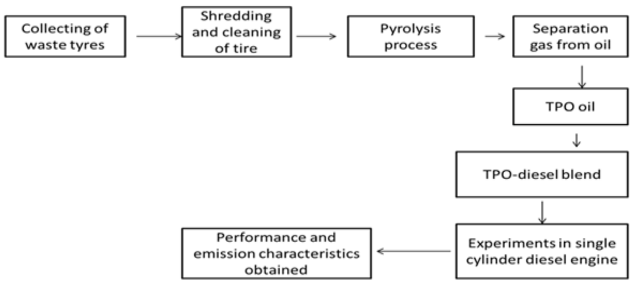


Figure.1. Methodology flow chart

- In this current investigation the oil which is obtained by the pyrolysis of the waste automobile tires.
- In the early stage the test to be performed on the single cylinder diesel engine by using diesel and base line data will be created.
- In the second stage of the experimental investigation will be carried out on the same engine with same operating parameter by using the tire pyrolysis oil (TPO) blended with diesel.
- In different extent such as 10, 20 and 30% of TPO-diesel blend to find the performance parameter and emissions.
- Finally the experimental investigation will be carried in a single cylinder diesel engine with TPO-diesel blend.

3. EXPERIMENTAL SETUP OF PYROLYSIS PROCESS

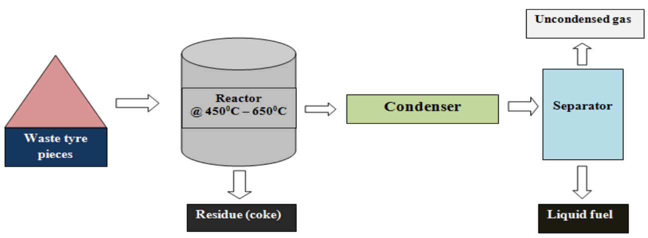


Figure.2. Block diagram of pyrolysis process

Figure.3. Pyrolysis process work setup

Pyrolysis is a thermo-chemical decomposition of organic material at a elevated temperature in the absence of oxygen. It involves the simultaneous change of chemical composition and physical phase, and is irreversible.

Work carried out in pyrolysis process is as follows:

COLLECTION & IDENTIFICATION OF WASTE TIRE PIECES

Figure.4. Waste tire pieces

The collection of waste tyre is quite an easy task as compared to other wastes. The tyre wastes are abundant and can be obtained in large quantities from the households, Automobile punctured shops etc.

DEPOSITING THE WASTE TIRE PIECES INTO REACTOR (PYROLYZER)

Figure.5. Reactor (Pyrolyzer)

Reactor is made up of mild steel material with flanges are welded on both the ends. Asbestos gasket is cut on the size of flange and fitted with different sizes of bolt and nut. Externally heated by means of high flame gas cylinder. The pyrolysis is a simple process in which the organic substance is subjected to higher temperature about 450^{0}C to 650^{0}C. Due to this thermal cracking of the organic substance is obtained and finally the end products in the form of raw oil char and gas in absence of oxygen.

CONDENSATION OF THE GAS TO OBTAIN RAW FUEL

Figure.6. Condenser

Condenser is made up of aluminum material with number of coils to improve the efficiency of the condensation. After heating the waste tyre in the pyrolyzer, the gas is allowed to escape through the outlet, condenser is dipped into the water containing jar so as to condense the fumes to collect the RAW FUEL drop by drop through outlet valve.

Table.1. Properties of Crude TPO oil

Properties	Units	Crude TPO
Flash point	^{0}C	70
Fire point	^{0}C	77
Viscosity @40^0 C	C_p	3.4
Density	Kg/m^3	900

CONVERSION OF RAW FUEL INTO ITS PURE FORM BY THE PROCESS OF PURIFICATION

Once the RAW FUEL is obtained it is further subjected to purification process so as to obtain the fuel i.e. TPO (Tyre pyrolysis oil).

Purification of TPO: The modification of the crude TPO involves two stages

(i) Removal of moisture
(ii) Desulphurization

Removal of moisture

Initially crude TPO was heated upto 100ºC, in a cylindrical vessel for a particular period of the removal of moisture, before subjecting it to any further chemical treatment.

Desulphurization

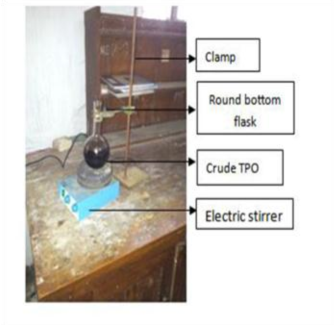


Figure.7. Desulphurization

The moisture free crude TPO contains impurities, carbon particles and sulphur particle. A known volume of concentric hydrosulphuric acid (8%) was mixed with the crude TPO and stirred well at a temp of 50^{0}C.

Table.2. Properties of purified TPO oil

Properties	Units	Purified TPO
Density	Kg/m^3	834
Flash point	˚C	68
Fire point	˚C	74
Viscosity @40^0 C	C_p	2.68
Calorific value	kJ/kg	42600
Cloud point	˚C	-6
Pour point	˚C	-3
Carbon content	%	84.67
Oxygen content	%	4.17

4. DESIGN DETAILS

REACTOR

Material – Mild steel
Outer diameter – 130 mm
Inner diameter – 116 mm
Height - 380 mm
Volume – 4015.96 m^2
Diameter of the outlet – 21 mm
Flange outer diameter – 230 mm
Heat supplied – 34.57MJ

CONDENSER

Tank capacity – 20Ltr
Heat capacity – 84KJ
No of coils – 8
Temperature range – 450-650^{0}C

5. ENGINE SETUP FOR PERFORMANCE TEST

Figure.8. Engine with Rope brake Dynamometer

To conduct performance test a single cylinder, 4-stroke, air cooled, DI diesel engine was used.
A Rope Brake Dynamometer connected to a resistive load bank, was used to load the engine. The fuel measuring system consisted of a burette to measure the rate of fuel consumed for given cc. The Tachometer was used to measure the speed of the shaft. Digital thermometer was used to measure the Exhaust Gas Temperature.
Performance, exhaust emission and combustion tests were carried out on the CI engine using blends of TPO-DF. All tests were conducted by starting the engine with DF only. After the engine was warmed up, it was then switched to TPO-DF blend. At the end of the test, the fuel was switched back to diesel and the engine was kept running for some time to flush out the TPO-DF blend by DF from the fuel line and the injection system, in order to prevent the fuel system from the accumulation of TPO-DF which may damage the system.

6. RESULT AND DISCUSSION

Table.3. For 10% blend (TPO-diesel)

Load (N)	Speed (Rpm)	Fuel Consumed in (sec)	Bp (KW)	mf (kg/hr)
5	1540	45	0.0711	0.6576
10	1529	42	0.1413	0.7045
15	1516	38	0.210	0.7787

FP (KW)	IP (KW)	Mech Efficiecy (%)	BSFC (kg/kw-hr)	BPth (%)
0.76	0.8311	10.2	9.248	9.01
0.76	0.9013	15.67	4.985	16.71
0.76	0.97	21.64	3.708	22.47

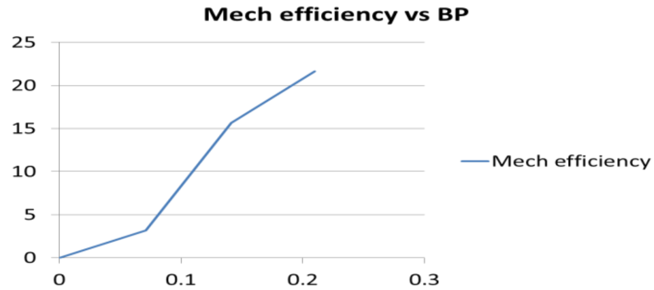


Figure.9. Mechanical efficiency Vs Brake power

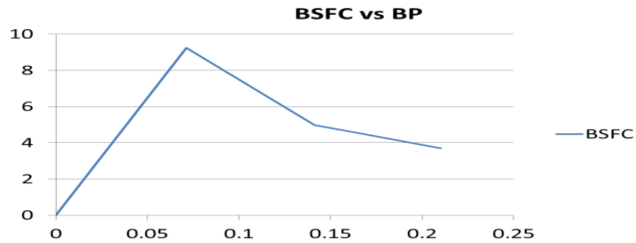


Figure.10. BSFC Vs Brake power

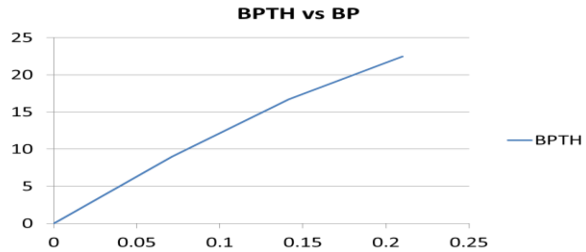


Figure.11. BPth Vs Brake power

Table.4. For 20% blend (TPO-diesel)

Load (N)	Speed (Rpm)	Fuel Consumed in (sec)	Bp (KW)	mf (kg/hr)
5	1500	45	0.0693	0.6428
10	1495	33	0.1382	0.8766
15	1485	28	0.205	1.0332

FP (KW)	IP (KW)	Mech Efficiecy (%)	BSFC (kg/kw-hr)	BPth (%)
0.18	0.2493	27.7	9.275	8.55
0.18	0.3182	43.43	6.342	12.53
0.18	0.385	53.2	5.04	15.83

FP (KW)	IP (KW)	Mech Efficiecy (%)	BSFC (kg/kw-hr)	BPth (%)
0.2	0.27	25.9	9.6385	8.29
0.2	0.3323	39.8	5.7702	13.85
0.2	0.398	49.7	4.3095	18.55

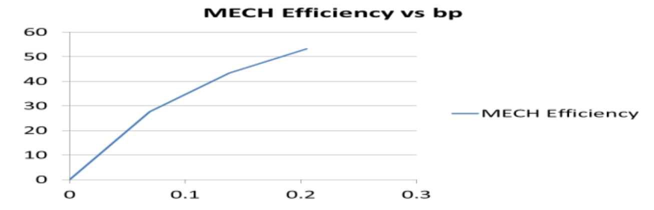


Figure.12. Mechanical efficiency Vs Brake power

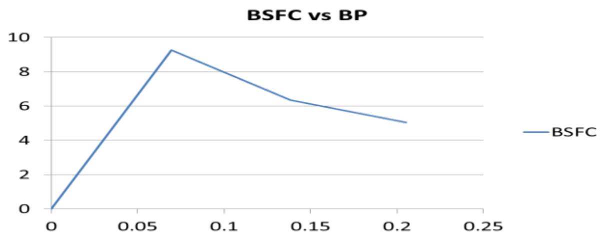


Figure.13. BSFC Vs Brake power

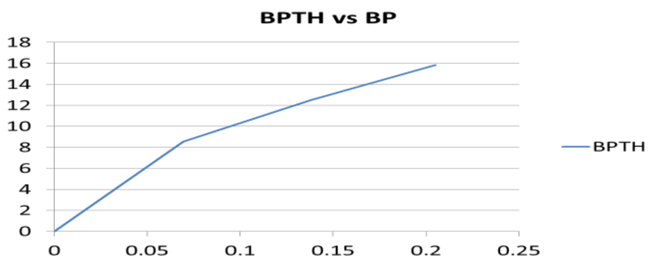
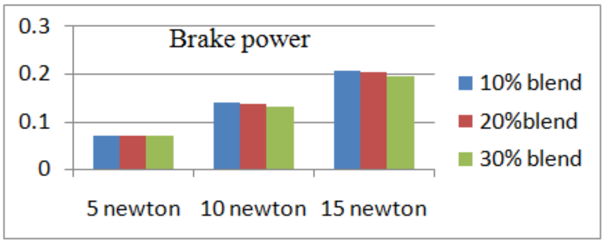
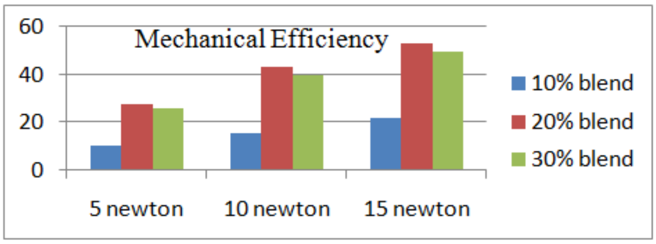


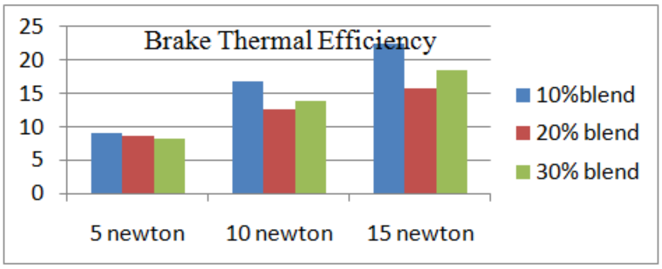
Figure.13. BPth Vs Brake power

Table.5. For 30% blend (TPO-diesel)

Load (N)	Speed (Rpm)	Fuel Consumed in (sec)	Bp (KW)	mf (kg/hr)
5	1528	43	0.070	0.6747
10	1432	38	0.1323	0.7634
15	1429	34	0.198	0.8533







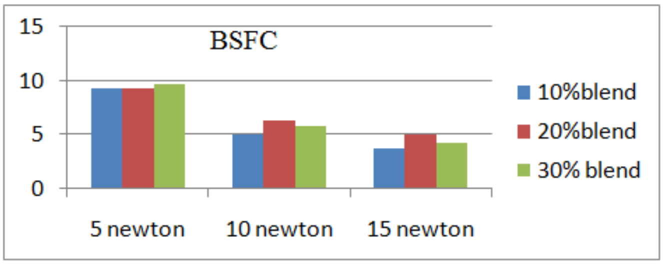


Figure.14. Comparision graphs for performance characteristics

EMISSION CHARACTERISTICS

Table.6. Emission test for 10 %(TPO-DIESEL)

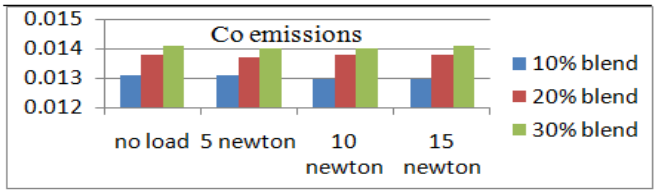
Load (N)	CO(% VOL)	HC(PPM)	CO_2(% VOL)
NO LOAD	0.0131	0.0012	0.0396
5	0.0131	0.0012	0.0396
10	0.0130	0.0011	0.0396
15	0.0130	0.0011	0.0396

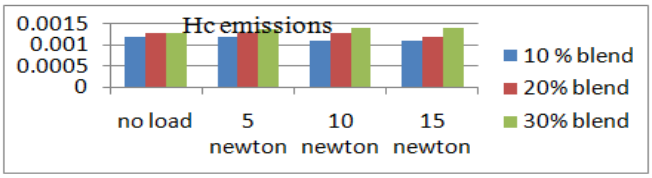
Table.7. Emission test for 20 %(TPO-DIESEL)

Load (N)	CO(% VOL)	HC(PPM)	CO_2(% VOL)
NO LOAD	0.0138	0.0013	0.0396
5	0.0137	0.0013	0.0398
10	0.0138	0.0013	0.0398
15	0.0138	0.0012	0.0398

Table.8. Emission test for 30 %(TPO-DIESEL)

Load (N)	CO(%VOL)	HC(PPM)	CO_2(% VOL)
NO LOAD	0.0141	0.0013	0.0398
5	0.0140	0.00139	0.0398
10	0.0140	0.0014	0.0399
15	0.0141	0.0014	0.0399





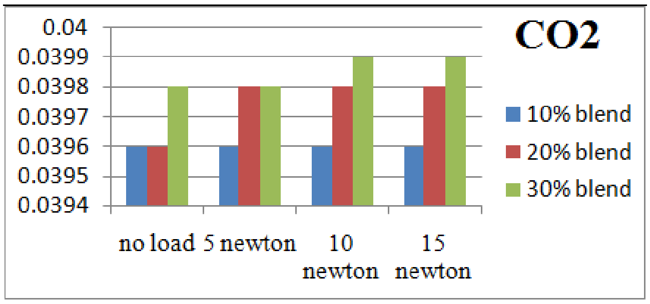


Figure.15. Comparision graphs for Emission characteristics

7. CONCLUSIONS

1. Brake thermal efficiency of the engine decrease with increase in TPO blend concentration than diesel fuel. Thermal efficiency for diesel fuel operation at different loads .in case of TPO 10% blend it is 22.47%. In case of 20% blend it is 15.83%. In case of 30% blend it is 18.55%.
2. The TPO-DF blend shows higher BSFC value than diesel due to lower calorific value of TPO-DF blend. As the load increase BSFC of the TPO-DF decreases
3. Mechanical efficiency of the TPO-DF increases with increasing load. For 10% the maximum efficiency obtained is 21.64%. In case of 20% blend it is 53.2%. And in 30% it is 49.7%.
4. The CO emission is higher at higher loads and is increasing with the blend ratio (TPO-DIESEL).
5. Similarly for HC emissions at higher loads the HC emission is high.
6. For the CO_2 emission at 30% blend the emission level is high in all the load conditions.

REFERENCES

[1] Murugan S, Ramaswamy MC, Nagarajan G. Assessment of pyrolysis oil as an energy source for diesel engines. Fuel Process Techno 2009; 90:67-74.

[2] Dhananjaya M, Gokul G, Ebenezer Sathish Paul P, K.R.Viswanathan, Ahamed Hussain M. Performance and Emission test on Tyre Pyrolysis oil blended with diesel on Research Advances in Mechanical Engineering (RAME'16)

[3] C. Wongkhorsub "A comparison of the use of pyrolysis oils in diesel engine" scientific journal-July 2013

[4] B. Kiran Kumar, Nayudu Lakshmi Deepak, PothulaAvinash. Performance and Emission Characteristics of Bio-Diesel using Tyre Pyrolysis oil. SSRG International

Journal of Mech Engineering (SSRG-IJME) – volume 2 Issue 3–March 2015

[5] Trilok Kumar, Lava Kumar. International Journal of Innovative Research in Science, Engineering and Technology Vol. 4, Issue 7, July 2015.

[6] Juan Daniel Martinez et al. 2014, Potential for using a tire pyrolysis liquid-diesel fuel blend in a light duty engine under transient operation, 4, 50018 Zaragoza, Spain.

[7] RokVihar "combustion characteristics of tire pyrolysis oil in turbo charged compression ignition engine" science direct fuel 150(2015)226-235