Extraction of Bio-Diesel Pyrolytic Oil from Bio-Medical Waste and Experimental Investigation of Engine Characteristics

Chandrashakhar[1] Harishchandra Astagi[2]
[1]M.Tech. Student [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]PDA College of Engineering Gulbarga, Karnataka

Abstract— Environmental concern and availability of petroleum fuels have caused interests in the search for alternate fuels for internal combustion engines. Conversion of waste to energy is one of the recent trends in minimizing not only the waste disposal but also could be used as an alternate fuel for internal combustion engines. Bio medical Wastes are indispensable materials in the modern world and application in the medical field is continually increasing. Bio medical waste pyrolysis oil of petrol grade and diesel grade and its blend with diesel and petrol respectively has been introduced as an alternative fuel. In this study, various operating parameters have been prepared for better understanding of operating conditions and constrains for bio medical waste pyrolysis oil of both grade fuel and its blends fuelled in compression and spark ignition engine.

Key words: Bio-Medical Waste, Bio-Diesel Pyrolytic Oil

I. INTRODUCTION

The transportation sector faces a major crisis and huge shortage of petroleum diesel for its applications. It is very much necessary for the researches to find an alternative way for the fuel to be used effectively in internal combustion engine. Public concern over disposal and treatment of medical waste has resulted in increasing regulations and court actions. The phenomenon increase in the quantity of medical waste generated in the hospital is attributed to the growing use of disposables. A rule of the thumb for medical waste production in affluent countries seems to be 1kg per bed per 8h shift. Hospitals and other health care units and research facilities in our country produces of millions of tons of waste every year.In many countries, medical waste can no longer be disposed in landfills, unless it is so thoroughly disinfected as to pose no risk to human health. Hospitals, health caring grades maternity and nursing homes, and research facilities produce large quantities of hazardous waste. This includes human anatomical waste, blood and body fluid, microbiological waste, animal waste, highly infantry's ways, discarded medicines, disposes, etc.

II. LITERATURE REVIEW

C. Wongkhorsub, N. Chindaprasert [1] conducted experiment on Comparison of the Use of Pyrolysis Oils in Diesel Engine concluded that the plastic pyrolysis oil offers lower engine performance, the plastic waste amount is enormous and it needed to be process to reduce the environmental problems. Moreover, the engine can be modify follow the combustion condition of plastic pyrolysis oil. The waste plastic used in the process must be PE or PP in order to protect the contamination of chlorine in the oil. Tire pyrolysis offers comparable efficiency to diesel oil in medium to high load but it has been question on the desulfurization process. Therefore, the development of the tire pyrolysis oil is depending on the cost of desulfurization process. Although the tire pyrolysis oil offer better quality than plastic pyrolysis oil, the amount of waste tire is minimal compare to plastic waste and the oil production is less. Additionally, by product of the tire pyrolysis plant carbon residue and tire wire from waste tire, the plant entrepreneur need to find an opportunity to process these byproducts due to the amount of the by product is correspondent to the oil product. Turning waste to energy is not only financial profit- able but it also environmental friendly business which the government should offer a strong policy to encourage the entrepreneur to invest in the waste to energy business.

Anup T J, Vilas Watwe [2] conducted experiment on Waste Plastic Pyrolysis Oil as Alternative For SI and CI Engines concluded that,

- Petrol Engine was able to run with 100% waste plastic oil.
- Engine fuelled with waste plastic pyrolysis oil exhibits higher thermal efficiency up to 50% of the rated power for petrol engine.
- Engine fuelled with waste plastic pyrolysis oil exhibits higher thermal efficiency up to 75% of the rated power for diesel engine.
- The exhaust gas temperature for waste plastic pyrolysis oil is higher than diesel and petrol for engine performance.
- Unburned hydrocarbon emission of waste plastic pyrolysis oil is less than that of diesel and petrol; for the different load.
- The NO_x emission in waste plastic oil varies from 55 ppm to 91 ppm for petrol grade fuel of plastic oil, and for diesel grade fuel of plastic oil varies from 192 ppm to 1268 ppm.
- CO emission increased by 5% in waste plastic oil compared to diesel operation.
- The CO_2 concentration increases with increase in load, due to incomplete combustion.

Pawar Harshal R. and Lawankar Shailendra M. [3] conducted experiment on Waste plastic Pyrolysis oil Alternative Fuel for CI Engine concluded that Based on the reviewed paper for the performance and emissions of waste plastic Pyrolysis oil, it is concluded that the waste plastic Pyrolysis oil represents a good alternative fuel for diesel and therefore must be taken into consideration in the future for transport purpose. Further it is concluded that,

1) Engine was able to run with 100% waste plastic oil.
2) Engine fueled with waste plastic oil exhibits higher thermal efficiency up to 75% of the rated power.
3) Brake thermal efficiency of the engine fueled with waste plastic oil with retarded injection timing is found to be higher.
4) At full load the brake thermal efficiency decreases with increase in EGR flow rate.

5) At the full load the Bsfc is higher WPPO blends show the specific fuel consumption higher than the diesel
6) The exhaust gas temperature for plastic oil is higher than diesel.
7) Unburned hydrocarbon emission is higher by about 15% than that of diesel; with the retarded injection timing it can be reduced.
8) The NOx emission in waste plastic oil varies from 14.63 to 8.56 g/ kWh without EGR compared to 10.97–8.2 g/kWh with 20% EGR. The NOx emission reduces with increase in EGR percentage, due to the presence of higher heat capacity gases that reduces the peak combustion temperature.
9) CO emission increased by 5% in waste plastic oil compared to diesel operation. x. The CO2 concentration decreases with increase in EGR percentages, due to instability in combustion.

III. BIOMEDICAL WASTE

'Bio-medical waste' means any solid and/or liquid waste including its container and any intermediate product, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research pertaining there to or in the production or testing thereof.

WHO stated that 85% of hospital wastes are actually non-hazardous, around 10% are infectious and around 5% are non-infectious but hazardous wastes. In the USA, about 15% of hospital waste is regulated as infectious waste. In India this could range from 15% to 35% depending on the total amount of waste generated.

Fig. 1: Bio medical wastes

A. *Sources of Bio Medical Waste:*

The management of bio-medical waste is still in its infancy all over the world. There is a lot of confusion with the problems among the generators, operators, decision-makers and the general community about the safe management of bio-medical waste. The reason may be a lack of awareness. Hence resource material on the environment for hospital administrators, surgeons, doctors, nurses, paramedical staff and waste retrievers, is the need of the hour

Medical care is vital for our life, health and well-being. But the waste generated from medical activities can be hazardous, toxic and even lethal because of their high potential for diseases transmission. The hazardous and toxic parts of waste from health care establishments comprising infectious, bio-medical and radio-active material as well as sharps (hypodermic needles, knives, scalpels etc.) constitute a grave risk, if these are not properly treated or are allowed to get mixed with other municipal waste. Its propensity to encourage growth of various pathogen and vectors and its ability to contaminate other non- hazardous/non-toxic municipal waste jeopardises the efforts undertaken for overall municipal waste management.

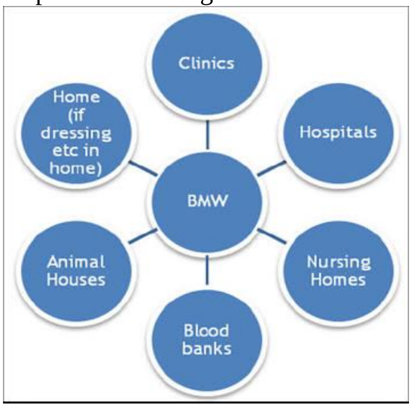

Fig. 2: Sources of biomedical waste

B. *Classification of Bio Medical Waste*

The rag pickers and waste workers are often worst affected, because unknowingly or unwittingly, they rummage through all kinds of poisonous material while trying to salvage items which they can sell for reuse. At the same time, this kind of illegal and unethical reuse can be extremely dangerous and even fatal. Diseases like cholera, plague, tuberculosis, hepatitis (especially HBV), AIDS (HIV), diphtheria etc. in either epidemic or even endemic form, pose grave public health risks. Unfortunately, in the absence of reliable and extensive data, it is difficult to quantify the dimension of the problem or even the extent and variety of the risk involved. With a judicious planning and management, however, the risk can be considerably reduced. Studies have shown that about three fourth of the total waste generated in health care establishments is non-hazardous and non-toxic. Some estimates put the infectious waste at 15% and other hazardous waste at 5%. Therefore with a rigorous regime of segregation at source, the problem can be reduced proportionately. Similarly, with better planning and management, not only the waste generation is reduced, but overall expenditure on waste management can be controlled. Institutional/Organizational set up, training and motivation are given great importance these days. Proper training of health care establishment personnel at all levels coupled with sustained motivation can improve the situation considerably.

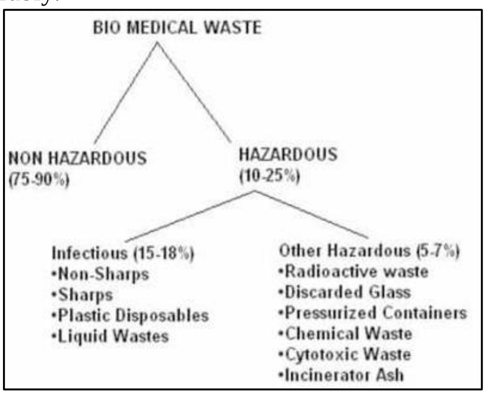

Fig. 3: Classification of biomedical waste

The rules framed by the Ministry of Environment and Forests (MOEF), Govt. of India, known as 'Bio-medical Waste (Management and Handling) Rules, 1998,' notified on 20th July 1998, provides uniform guidelines and code of practice for the whole nation. It is clearly mentioned in this rule that the 'occupier' (a person who has control over the concerned institution / premises) of an institution generating bio-medical waste (e.g., hospital, nursing home, clinic, dispensary, veterinary institution, animal house, pathological laboratory, blood bank etc.) shall be responsible for taking necessary steps to ensure that such waste is handled without any adverse effect to human health and the environment.

Diesel engines and petrol engines are the most efficient prime movers, from the point of view of protecting global environment and concerns for long-term energy security it becomes necessary to develop alternative fuels with properties comparable to petroleum based fuels. Unlike rest of the world, India's demand for diesel fuels is roughly six times that of gasoline hence seeking alternative to mineral diesel is a natural choice.

Alternative fuels should be easily available at low cost, be environment friendly and fulfil Energy security needs without sacrificing engine's operational performance. Waste to energy is the recent trend in the selection of alternate fuels. Fuels like alcohol, biodiesel, liquid fuel from plastics also from medical waste etc. are some of the alternative fuels for the internal combustion engines. Utilization of biomass as alternative fuel for compression ignition engine has a great scope especially in developing and undeveloped countries.

Medical waste has become an indispensable part in today's world, due to their undetermined use in hospitals and also faster rate of production. At the same time, waste bio medical waste has created a very serious environmental challenge because of their huge quantities and their disposal problems. Through the thermal treatment on the bio medical waste the fuel can be derive, by adopting the chemical process such as Pyrolysis can be used to safely convert wastes into oil blends.

Due to abundant availability of bio medical waste and because of more disposal problem, these wastes can be converted into oil blends by pyrolysis process and which can be used to run the diesel engine.

IV. PYROLYSIS

Feedstock material is the main factor to indicate the properties of the pyrolysis oil. Tire pyrolysis and plastic pyrolysis technologies are the available technologies on the market in Thailand. The feedstock pre-process is one of the main factors to assess the possibility of the technology. The waste tires are collected easily from the scavenger and garage as they are bulky and heavy but only shredding process is required to reduce the size. The medical waste plastics are collected from hospitals, nursing homes and such area where the medical waste available. The weakness of the plastic is the character of the plastic, which is mainly from plastic, is small high impurity and bulky. Soring and cleaning is required for plastic process. However, as the purpose of the process is turning waste to energy, the pyrolysis process of tire and plastic is distinguished and compared in this research. Physical and chemical analysis properties of both oils are studied and compared in order to ensure to usage of the oil in diesel engine.

Pyrolysis is the initial process that takes place when organic matter is first heated in the absence of oxygen to produce combustible gases. Pyrolysis by itself does not normally release excessive heat; rather, it requires heat to sustain it. Pyrolysis of organic materials such as biomass at high temperatures (greater than 428° F) decomposes the fuel source into charcoal (carbon and ash) and volatile matter. The latter comprises condensable vapours called pyrolysis oil (also known as bio-oil, bio crude, etc.) at room temperatures and non-condensable (permanent) gases such as carbon monoxide, carbon dioxide, hydrogen and light molecular weight hydrocarbon gases such as methane, collectively called synthesis gas (syngas or producer gas).

A. *Types of Pyrolysis Technologies*

Pyrolysis technologies can be categorized as being of two types:

- Fast Pyrolysis, and
- Slow Pyrolysis.

1) *Fast Pyrolysis*

Fast pyrolysis (Flash pyrolysis) takes place in less than two seconds with temperatures between 300 and 550 degrees Celsius. Char accumulates quickly in fast pyrolysis and must be removed frequently.

Fast Pyrolysis can be further categorized into the following:

- Ablative Fast Pyrolysis - pressure is applied to biomass to increase speed of decomposition through use of centrifugal or mechanical force. Larger particles of biomass can be used in this process.
- Cyclonic Fast Pyrolysis - also called vortex fast pyrolysis, separates the solids from the non-condensable gases and returns them to the mixer.
- Rotating Cone Fast Pyrolysis - uses a compact high intensity reactor in which biomass of ambient temperature is mixed with hot sand. Upon mixing with the hot sand, the biomass decomposes into 70% condensable gases with 15% non-condensable gases and 15% char.

B. *Plastic Pyrolysis Oil*

In the USA, plastic waste approximately 31 million of tons was generated in 2010 which is about 17.45% of total waste by weight as shown in Table 1. The percentage of the plastic waste is also similar in Thailand and around the world. As known that plastic is a non- degradable petroleum based product. The old landfill area is found that degradable product is composted, be- come soil while plastic is still exist. This problem is solved by converting waste plastic to energy by pyrolysis process. As the petroleum based plastic is the polymeric material, the plastic pyrolysis process is the thermal de-polymerization process in the absence of oxygen which is able to convert plastic into gasoline-range hydrocarbons. The waste plastic used in pyrolysis process is needed to be sorted and cleaned. The Polyethylene (PE) and Polypropylene (PP) which are the main component of the plastic in municipal solid waste are used in the process in order to prevent the contamination of chlorine in the oil. The classified waste plastic is processed from an autoclave pyrolysis reactor. In general, product yields from pyrolysis are varied with temperature. The plastic pyrolysis oil used in this research is processed at 300-500°Cat atmospheric pressure for 3 hours. The product output consists of 60-80% pyrolysis oil, 5-10% residue and the rest is pyrolysis gas on weight basis. The plastic pyrolysis oil used in this research is processed from a commercial waste plastic pyrolysis plant in Thai- land.

C. Plastic pyrolysis Process

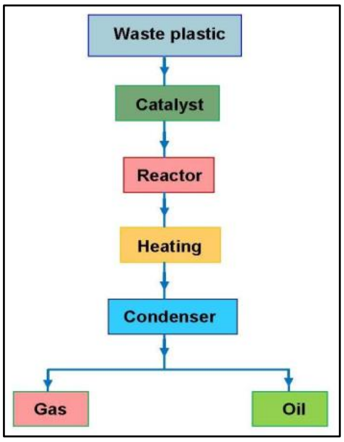

Fig. 4: Flow chart for extraction of oil from biomedical waste plastics

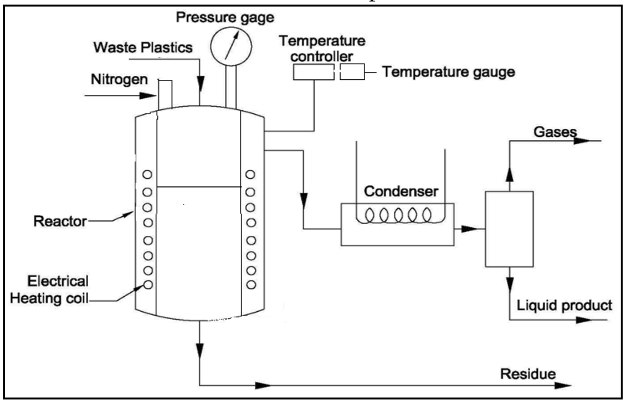

Fig. 5: Oil extraction plant for waste plastics

Fig. 6: Pyrolytic equipment

The Oil extraction plant consist of

- Reactor
- Condenser
- Temperature controller
- Pressure gauge

1) Reactor: The reactor consists of electrical heating coil and bricks around the reactor where the combustion takes place.
2) Condenser: In condenser the change of phase takes place i.e. vapour to liquid.
3) Temperature controller: The temperature controller controls and sets the temperature which is required for reactor to carryout combustion.
4) Pressure Gauge: Pressure gauge indicates the pressure in the reactor.

D. Plastic Pyrolytic Process

The collected bio medical plastic waste is fed in to the reactor and by regulating the valve vacuum is created inside the reactor. Continues water supply is provided to condenser. Reactor is surrounded by heating coils and bricks and the nitrogen as inert gas is passed through the valve which is situated at the top of the reactor. Purpose the passing inert gas is reduce the formation of black carbon and to balance atmospheric pressure inside the reactor. Temperature is set up to 500^{0}c and heater is kept on and the waste material in the reactor is allowed to boiling after attaining required temperature the waste material is converted to vapours which is passes through the condenser where the vapour is condensed to liquid hence obtaining the bio medical waste pyrolytic oil along with some HC gas, Carbon black.

When the 1000kgs of plastic waste is used in the pyrolysis we can get 650-900lit of pyrolysis oil, 50-100kg of hydrocarbon gas and 50-70kg of carbon black.

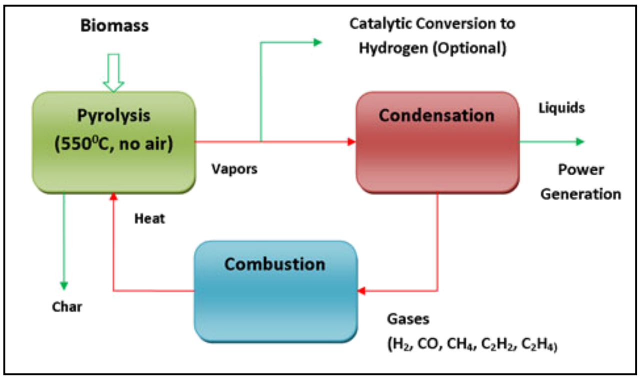

Fig. 7: Pyrolytic Process

E. Advantages of Pyrolysis

1) The process of making bio oil is relatively simple and quick.
2) All of the biomass components can be processed into fuel product; none are wasted during the pyrolysis process.
3) Pyrolysis reactors are relatively simple and have reached some level of commercial production.
4) A fast pyrolysis facility can be built on relatively small, mobile scale in order to produce bio oil close to the bio mass source and then transport it into to a central facility to be upgraded.

V. EXPERIMENTAL SET UP

The Oil extraction plant consist of

- Reactor
- Condenser
- Temperature controller
- Pressure gauge

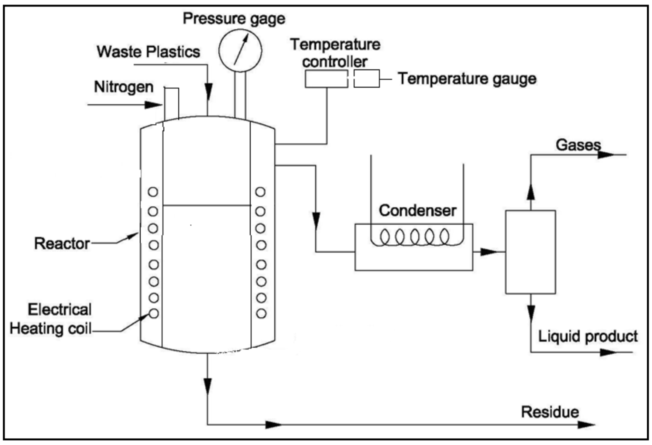

Fig. 8: Oil extraction plant for waste plastics

1) Reactor: The reactor consists of electrical heating coil and bricks around the reactor where the combustion takes place.
2) Condenser: In condenser the change of phase takes place i.e. vapour to liquid.
3) Temperature controller: The temperature controller controls and sets the temperature which is required for reactor to carryout combustion.
4) Pressure Gauge: Pressure gauge indicates the pressure in the reactor.

Fig. 9: Photograph of the experimental setup

VI. RESULT AND DISCUSSION

A. *Brake Thermal Efficiency with Brake Power*

Figure shows the variation of brake thermal efficiency with brake power for various blend proportion with diesel fuel. the efficiency varied from 1.42% at low load to 27.45% at 14.16kg of load and it decrease to 24.07% at full load for diesel fuel. The efficiency varied from 0.48% at lower load to 27.75% at14.16kg of load and it deceases to 23.94% at full load for B20(PO20) blended with diesel fuel at the injection pressure of 200bar. And also the efficiency varied from 0.2% at lower load to 33.44% at full load for B40(PO40).the efficiencies for B60,B80 and B100 are 31.33%,29.31% and 23.74 respectively at full load. It may be observed that the brake thermal efficiency is increased from 24.07% to 33.44% at full load for B20 and B40 respectively, when the fuel injection pressure is 200bar.

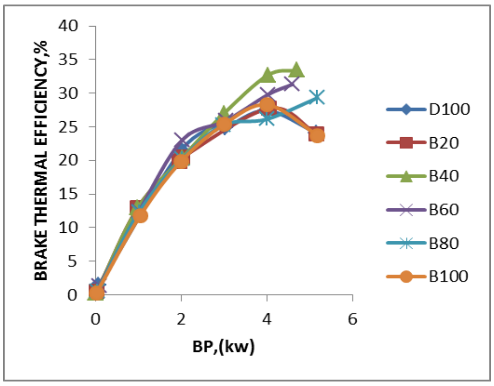

Fig. 10: Variation of Brake thermal efficiency with Brake power

B. *Specific Fuel Consumption with Brake Power*

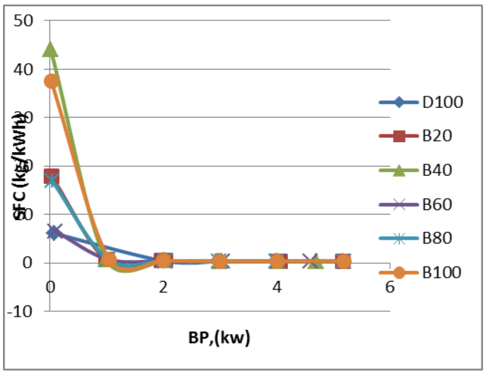

Fig. 11: Variation of Specific fuel consumption with Brake power.

Fig. shows the variation in Specific fuel consumption with load for different Blend Proportions. Specific fuel consumption decreases with increase in load. It is very much clear from the graph that Specific fuel consumption is maximum for 40% of blend than any of the Blend Proportion at lower loads. And SFC is maximum for 100% of pyrolysis oil at higher load. Specific fuel consumption is decreasing with increase in Blend proportion of plastic pyrolysis oil in diesel fuel from B20 to B40, This is also because of the same reason for decrease in fuel consumption with increase in blend percentage of plastic pyrolysis oil. Due to higher calorific value of the plastic pyrolysis oil, enough required heat can be produced with lesser amount of fuel. and increases from B40 to B100, due to the lower calorific value of PO-DF blends. The amount of fuel necessary to deliver the same power output with PO-DF blends is higher with increasing the percentage of PO.

C. *Variation of Air Fuel Ratio with Brake Power*

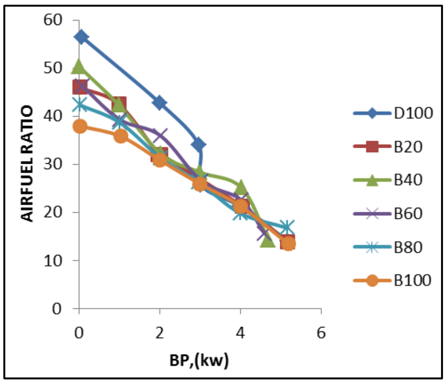

Fig. 12: Variation of Air fuel ratio with Brake power

Fig. shows the air fuel ratio of plastic pyrolytic oil blends and diesel comparing between air fuel ratio and brake power. High latent heat of vaporization and high volatility so it will vaporize easily to form a homogenous mixture with air. B100 is best for low fuel consumption. At no load conditions the D100 has the highest air fuel ratio of 56.45 as compared to any other blend proportions, it seems that the PPO-DF blends has less air fuel ratio compared to diesel fuel at no load condition.

D. Variation of Mechanical Efficiency with Brake Power

Fig.13 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, different Fuels and Blends, we get maximum Mechanical Efficiency for B80.

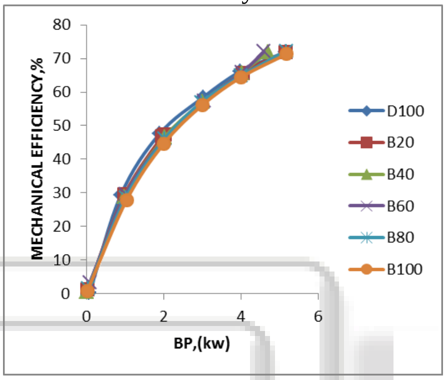

Fig. 13: Variation of Mechanical efficiency with Brake power

Increasing Blending ratio from 20% to 80%, gives positive impact on Mechanical Efficiency as it seems increasing. This increase in Mechanical Efficiency reduces after 30% proportion of plastic pyrolysis oil in diesel fuel. It becomes almost constant up to the 100% proportion of plastic pyrolysis oil and efficiencies of 80% and 100% blends are almost similar, which is nearly comparable to diesel fuel. So, in Mechanical Efficiency, the comparison of Mechanical Efficiency for Different Fuel and Blends at different loads is easily visible and understood from the figure.

E. Volumetric Efficiency with Brake Power

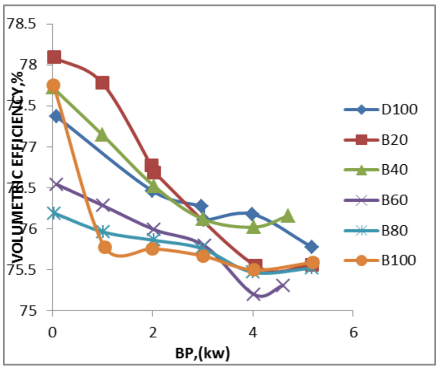

Fig. 14: Variation of Volumetric efficiency with Brake power

The figure shows that the variation of volumetric Efficiency with load for different proportions. At no load conditions the volumetric efficiency is high for B20 compared to B100. B80 has the lowest efficiency of 76.19% at no load conditions compared to others. And at higher loads B40 has the highest efficiency of 76.16%. B60 has the lowest of 75.31%. At load 1 there is a sudden decrease in volumetric efficiency for B100 compared to other blends. The graph for the blends are in zigzag in nature because of breathing of engine for particular combinations that is ratio actually indused at ambient conditions to the swept volume of engine.

F. Exhaust Gas Temperature with Brake power

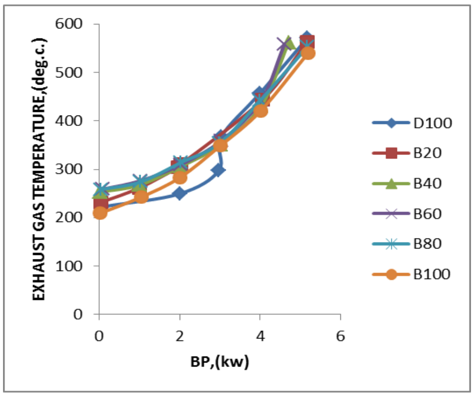

Fig. 15: Variation of Exhaust Gas Temperature with Brake power

Figure shows the exhaust gas temperature variation with brake power. It may be seen that the exhaust gas temperature increases with increasing load and decreases with increase in the blend concentration and the values are lesser compared to DF. The exhaust gas temperature varies from 222.6 °C at no load to 570.62°C at full load for DF whereas it varies from 231.46°C at no load to 563.63°C at full load for B20. For B40 it varies from 252.9 °C at no load to 561.23°C at full load. And it goes on decreasing, for B60,B80 and B100 are 558.63°C, 553.75°C, and 540.14°C respectively at full load. The reasons for lower exhaust gas temperatures for PO- DF blends are due to lower viscosity which results a lesser penetration of the fuel into the combustion chamber and the lesser amount of heat is developed.

G. Emission Characteristics

1) Hydrocarbon Vs. Brake power

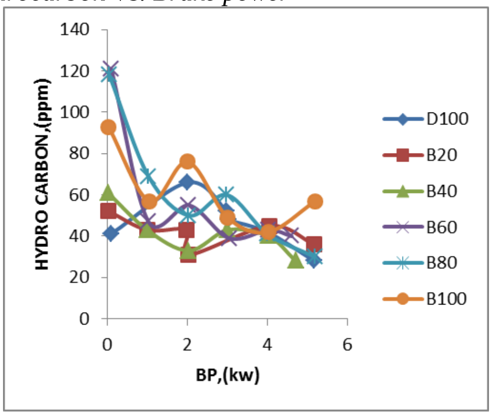

Fig. 16: Variations of Unburnt Hydrocarbon Vs Brake power

Figure16 shows the variation of Hydrocarbon (HC) emissions for the plastic pyrolysis oil with diesel fuel at different loads. HC emissions for PO-DF are higher compared to DF at full load. Part load values for PO-DF are marginally closer to DF. HC varies from 28 ppm to 66 ppm for DF. It can be observed that for B20, it varies from 31 ppm to 52 ppm, for B40 from 28 ppm to 61 ppm , for B60 from 39 ppm to 121 ppm,for B80 and B100 varies from 30ppm,42ppm to118ppm, 93ppm respectively. Higher HC emissions are probably due to higher viscosity, density, poor volatility and fuel rich mixtures at higher loads. Part load values for PO-DF are marginally closer to DF.

2) Carbon dioxide Vs Brake power

Fig. 17 shows the variation of carbon dioxide with load at different proportions. At no load conditions B20 has the minimum Carbon dioxide Emission compared to other blends i,e. 2.72% and at load 2 B100 has high i,e 4.39% later there is increase in load then the emission decreases finally at full load it was 3.53% similarly for D100 at no load conditions carbon dioxide emission is 2.91% and it has higher emission at load 1 that is 3.76%, later at full load it will decreases and reaches to 1.8% , similarly for all blends i,e B20,B40,B60,B80 also carbon dioxide emissions are ecreasing with increase in load. .

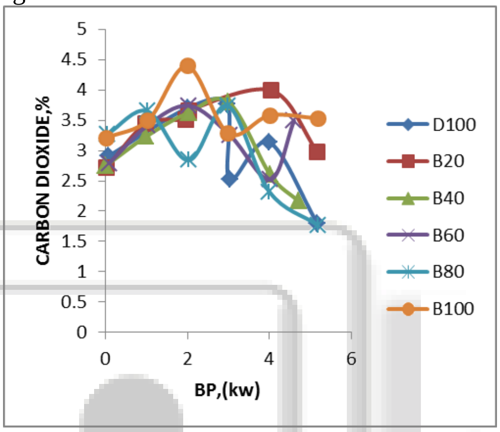

Fig. 17: Variations of Carbon dioxide Vs Brake power

3) Carbon Monoxide Vs Brake Power

Figure18 shows the comparison of Carbon monoxide emission with brake power. Generally, CI engines operate with lean mixtures and hence the CO emission would be low. CO emission for the PO-DF blends is less compared to DF. The concentration vary from 0.01% to 0.16% for diesel fuel and 0.01% to 0.13% forB20, whereas it varies from 0.01% to 0.1% for B40.for B60 it varies from 0.01% to 0.21%, and for B80 and B100 it varies from 0.01%,0.01% to 0.22%,0.45% respectively. B40 gives less CO emission compared to any other blended fuels and diesel fuels. B100 gives the maximum CO emission is 0.45% at full load. It is because the fuel air mixture filled inside the cylinder is very lean and some of the mixtures nearer to the wall and crevice volume, the flame will not propagate.

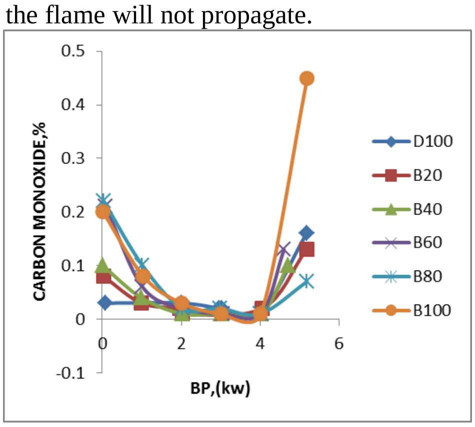

Fig. 18: Variations of Carbon monoxide Vs Brake power

4) Oxides of nitrogen Vs Brake power

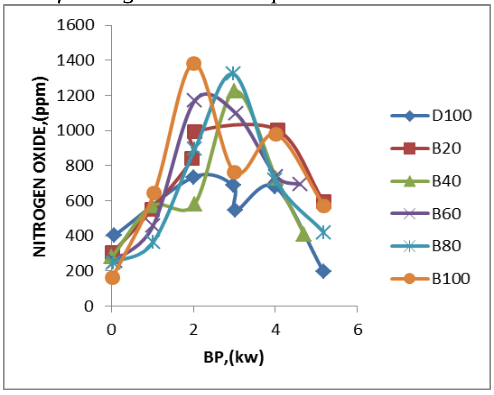

Fig. 19: Variations of Oxides of nitrogen Vs Brake power

NOx emissions are compared and depicted in Figure19. NOx varies from 404 ppm at no load to 688 ppm at 14.16kg of load and it sudden decreases to 198ppm at full load for diesel fuel. It can also be observed that NOx varies from 305 ppm at no load to 1003 ppm at 14.16kg of load and decreases to 596 ppm at full load for B20 and for B40 it varies from 279 ppm at no load to 1224 at 10.5kg of load and it decreases to 409ppm at full load. For B60 it varies from 256ppm at no load to 1169ppm at 10.41kg of load and decreases to 693ppm at full load.

H. Combustion Characteristics

1) Pressure with Crank Angle

Fig. 20 shows the typical variation of cylindrical pressure with respect to cranck angle. In CI engine the cylindrical pressure is depends on the fuel burning rate during the premixed burning phase, which in turn leads better combustion and heat release. The cylindrical Pressure of D100,B20,B40,B60,B80 and B100 is increases up to the crank angle 370 deg. and then decreases. The cylindrical pressure of B100 is 69.07bar at the crank angle 370 deg is the highest pressure. cylindrical pressure of PO-DF blends are highest compared to DF at the crank angle 370deg. due to higher calorific value of PO-DF blended oil. further cranck angles the cylindrical pressure falls below D100.

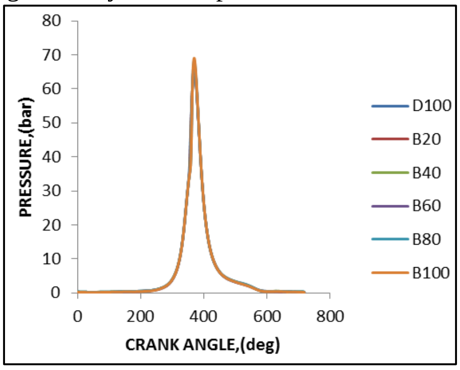

Fig. 20: Variation of pressure with crank angle

2) Cumulative Heat Release Rate with Crank Angle:

The variation of cumulative heat release rate with crank angle is shown in Figure21. The cumulative heat release rate of B100, B20, B40, B60, B80 is found to be lesser compared to diesel fuel. At ZERO angle the CHRR value for all blend proportions are zero. At initially there is little decrease in CHRR, this is due to the ignition of fuel air mixture prepared during the delay period. And as the crank angle increases gradually the value of CHRR increases. And at 475 deg to 499 deg there is a sudden increases in CHRR value for all blends and diesel 100% but comparatively D100 has the maximum CHRR of 1.36kj compared to other blends at this stage, due to the reason that the fuels with longer ignition delay shows higher rate of heat release at initial stage of combustion and increase in cylinder peak pressure and from that 499deg again there is decrease in the CHRR of all blends.

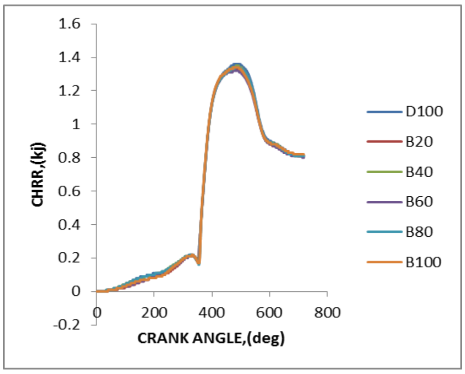

Fig. 21: Variation of Cumulative heat release rate with Crank angle

3) Net Heat Release Rate with Crank Angle:

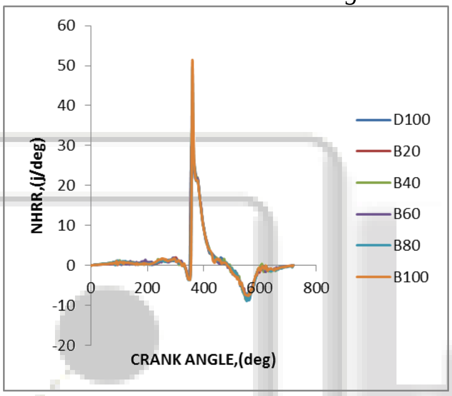

Fig. 22: Variation of net heat release rate with Crank angle

The variation of net heat release rate with crank angle is shown in Figure22. The B100 has the higher net heat release rate at cranck angle 360 deg and for further cranck angles the net heat release rate decreases. The net heat release rate increases with increasing blend percentage of PO-DF. .The heat release rate for all other tested fuel was higher then that of the diesel fuel up to the crank angle 360 deg, and from 360deg crank angle heat release rate for all other tested fuel was slightly less then that of diesel fuel. This may be attributed to low vaporization, high viscosity and low peak pressure of blends as compared to that of diesel fuel. This is due to premixed and uncontrol combustion phase. .

4) Net Mass Fraction Burned With Crank Angle

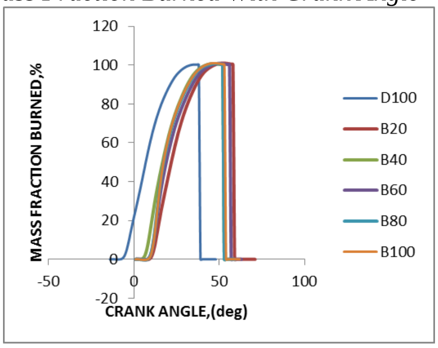

Fig. 23: Variation of net mass fraction burned with Crank angle

Fig23 shows that the variation of mass fraction burned with different crank angles. it is observed from the above graph that for all blends at zero crank angle the value of mass fraction burned is zero, but whereas for D100 it is in negative from certain value i,e -11deg . And there is a gradual increase of MFB for B20 upto the maximum value of 100.97 % at 36deg. And for B40 (100.79 at 37deg), B60 (101.86% at 38deg), B80 (100.77% at 38deg), B100 (101.04% at 36deg), D100 (100.33% at 36deg). Since from this observation we conclude that B60.

VII. CONCLUSION

From the present experimental investigation, following conclusions were derived,

- Pyrolysis process was one of the best methods to treat waste plastic under solid waste management technique.
- No engine seizing or injector blocking was found during the entire operation of the engine running with different percentages of WPPO–DF from 20% to 100%.
- Diesel Engine was able to run with 100% waste plastic oil. Brake thermal efficiency increases with increase in percentage of DPPO blends butB40 has the higher than DF. About 9% increases in the thermal efficiency is noticed.
- Engine fuelled with 40% of waste plastic pyrolysis oil with 60% of DF exhibits higher thermal efficiency up to 33% of the rated power for diesel engine.
- The exhaust gas temperature for waste plastic pyrolysis oil is lesser than diesel for engine performance.
- The exhaust gas temperature decreases with increase in blend proportion and the exhaust gas temperature for DF is higher than WPPO.
- Hydrocarbon emissions are higher for WPPO–DF blends than for DF at full load. B20 exhibits an approximately 8% increase in HC at peak load. In the cases of B40 it same as that of DF and B60, B80, and B100 the rises in HC at peak load are 12%, 2%, and 29% respectively.
- Carbon di-oxide emissions are also higher for WPPO–DF blends than for DF,
- CO emissions for WPPO-DF blends were lesser compared to diesel Operation, except B100, it has maximum CO emission i,e.0.45%.
- NOx emissions are higher for WPPO–DF blends than for DF. B20 exhibits an approximately 40% increase in NOx at full load compared to DF. In the cases of B40,B60,B80 and B100 the rise in NOx at full load are 21%,49%,22% and 37%, respectively.
- Peak pressure and the rate of pressure rise for TPO–DF blends are higher compared with DF.
- Higher rate of heat release in the initial stages and rate of pressure rise are observed in the WPPO-DF blends compared to DF. This is attributed to longer ignition delay of WPPO-DF blends.
- UNburnt hydrocarbon emission is higher than the diesel fuel operation.
- Higher CO2 show the oxidation of fuel good at part loads.
- Waste plastic pyrolysis oil can be used alternate fuel to the diesel.

REFERENCES

[1] N. L. Panwar, Y. H. Shrirame, N. S. Rathore, S. Jindal and A. K. Kurchania, "Performance Evaluation of a Diesel Engine Fueled with Methyl Ester of Castor Seed Oil," Applied Thermal Engineering, Vol. 30, No. 2-3, pp. 245-249, 2010. doi:10.1016/j.applthermaleng. 2009.07.007
[2] J.Janaun and N. Ellis. "Perspectives on Biodiesel as a Sustainable Fuel," Renewable and Sustainable Energy Reviews, Vol. 14, No. 4, 2010, pp. 1312-1320. doi:10.1016/j.rser.2009.12.011
[3] M. Lapuerta, O. Armas and J. R. Fernandez. "Effect of Biodiesel Fuels on Diesel Engine Emissions," Progress in Energy and Combustion Science, Vol. 34, No. 2, 2008, pp. 198-223. doi:10.1016/j.pecs.2007.07.001
[4] J. Walendziewski, Engine fuel derived from plastics by thermal treatment, fuel 81 (2002) 473-481
[5] M. Mani, G. NagarajaN, Influence of injection timing on performance, emission and combustion characteristics of a DI diesel engine running on waste plastic oil Energy 34 (2009) 1617–1623
[6] "Clean Alternative Fuels – Biodiesel," Environmental Protection Agency Fact Sheet, Document No. EPA420-F-00-032, March 2002.
[7] M. F. Ali, S. Ahmed, M. S. Qureshi, Catalytic coprocessing of coal and petroleum residues with waste plastics to produce transportation fuels Fuel Processing Technology 92 (2011) 1109–1120
[8] N. Miskolczi, A. Angyal, L. Bartha, I. Valkai, Fuels by pyrolysis of waste plastics from agricultural and packaging sectors in a pilot scale reactor
[9] F. Murphy, K. M. Donnell, E. Butler, G. Devlin, The evaluation of viscosity and density of blends of Cyn-diesel pyrolysis fuel with conventional diesel fuel in relation to compliance with fuel specifications EN 590:2009.