Indian J.Sci.Res. 15 (2): 57-61, 2017 ISSN: 2250-0138 (Online)

A REVIEW ON ENGINE PERFORMANCE AND EXHAUST EMISSION OF COMPRESSION IGNITION ENGINE USING PYROLYTIC PLASTIC FUEL

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ABSTRACT

Two sensitive issues like depletion of fossil fuel and exponential growth in pricing of petroleum product becomes a big challenge in modern world. The handling, management and disposal of solid waste are critically concerned in each developing country like India due to uncontrolled and increased disposal rates causing severe threat to the environment. Pyrolysis has been effectively proved as an influential alternative among other methods of waste disposal that follows waste to energy recovery. This review subscribes the effective methodology of pyrolytic conversion of waste plastic into energy sources in regards to its technologies and merchandise. In this review, first the different types of waste plastics are introduced followed by their sources and different waste management practices being practiced. Second part of the paper briefly summaries the Pyrolysis technology for treatment of waste plastics and the effect of important operating parameters such as temperature, heating rate and residence time in the reaction zone on the pyrolysis behaviours and products, reactor type, operating pressure and presence of catalyst. Finally, the composition, properties and uses of the pyrolytic liquid products are summarised to emphasize the suitability and sustainability of pyrolysis process for recycling of waste plastics.

KEYWORDS: Solid Waste, Pyrolysis, Energy Recovery, Waste Plastics, Operating Parameters, Pyrolytic Liquid.

Around the globe, researches are carried out on waste plastics disposals and its conversion into value additions. According to a nationwide survey, conducted in the year 2003, more than 15342.46Tof plastic waste is generated daily in our country, and only 40% by wt of the same is recycled, balance 60% by wt is not possible to dispose off (Guntur and Kumar). Plastic waste contributes to the solid waste streams by about 8% – 15% by weight and twice that by Volume (GOI, 1997).From this statically forecasting, it is anticipated that, the plastic waste will attain 11 million ton by the year 2020. At these critical levels of waste plastics generation, India has to take a well planed front towards preparing a solid waste recycling and disposal. However each process has certain limitations to come up with an economically viable, operationally sustainable & financially stable.

Plastic waste management is now become a biggest challenge as they are non- biodegradable in nature. Now plastics manage by plastics recycling technologies.

Table 1: Uses of different types of plastics [arun et al.]

Type of Plastics	Uses
Polyester	Textile fibres
PET	Carbonated drink bottles, plastics film
PE	Supermarket bags, plastics bottle
HDPE	Milk jugs, detergent bottles, thicker Plastics film, pipes
LDPE	Floor tiles, shower curtains
PVC	Agriculture (fountain) pipe, guttering Pipe, Window frame, sheets for building material
PS	Foam use for insulation of roofs and walls, Disposal cups, plates, food Container, CD and cassette box.
PP	Bottle caps, drinking straws, Bumper, house ware, Fiber carpeting and rope.

CI engines are the most preferred power plants than other internal combustion engines due to their excellent drivability and higher thermal efficiency [5]. Use of fossil fuel emits high amount of nitrogen oxides (NO_x), carbon dioxide (CO_2), Carbon monoxides (CO), Hydrocarbon (HC) and smoke, which will have a catastrophic effect on human health. Hence, stringent emission norms and depletion of petroleum fuels have necessitated the search for alternate fuels for diesel engine (Mani and Nagrajan). Demand of alternative fuels pertains at ease of availability with reasonable cost, environmental friendly and Energy security without hampering 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 etc. are some of the alternative fuels for the internal combustion engines. Application of Waste Plastic Disposals reduces the experimental heavy fuel oil viscosity. The results showed that waste plastic disposal oil when mixed with heavy oil reduces the viscosity significantly and improves the engine performance (Williams and Elizabeth). Although

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Oxides of Nitrogen (NOx) emission slightly increases, the emission of particulate matters (PM), dry soot (DS) and soluble organic fraction (SOF) decreases by half at the mixing ratio of 30% by vol. Such kind of plastic materials are HDPE, LDPE, PE, PP, Nylon, Teflon, PS, ABS, and FRP.

PYROLYSIS OF WASTE PLASTIC AND ITS PROPERTY

Pyrolysis is generally considered as a thermal degradation process in the absence of oxygen. In plastic pyrolysis, the macromolecular structures of polymers are broken down into smaller molecules or oligomers and sometimes non numeric units. It breaks large hydrocarbon chain into smaller ones, but this type of pyrolysis requires higher temperature and high reaction time, presence of catalyst and other process conditions.

Mechanism and Kinetics of Pyrolysis

The degradation of polymer may be considerably different based on the way in which reaction is carried out: heat (thermal degradation), heat and catalyst (thermo catalytic degradation), oxygen (oxidative degradation), heat and oxygen (thermo-oxidative degradation), radiation (photochemical degradation), radiation and oxygen (photo-oxidative degradation), chemicals (chemical gradation), etc.

The pyrolysis process is basically enumerated as non-catalytic and catalytic in nature. The non-catalytic pyrolysis of waste plastic requires high energy, endothermic process in absence of oxygen at a temperature range of 350-500^{0}C. In catalytic method, a suitable catalyst is used to carry out the cracking reaction. The presence of catalyst lowers the reaction temperature and time. In addition, catalytic degradation yields a much narrower product distribution of carbon atom number with a peak at lighter hydrocarbons and occurs at considerably lower temperatures. From an economic perspective, reducing the cost further will make this process even more attractive option.

Property Study of Pyrolytic Plastic Oil

Pyrolysis is a chemical degradation process in the absence of oxygen. Plastic waste are shredded and treated in a cylindrical reactor at different range of temperature varying from 300-500^{0}C. The pyrolysis is carried out with or without the presence of catalyst. Catalyst helps in degrading the waste plastic in very simpler form and generating gas which is condensed passing through the condenser.

Table 2: Properties of Waste Plastic Pyrolysis Oil and Diesel [Power and Lawankar]

Sl. No.	Properties	WPPO	Diesel
1	Density (kg/m^2)	793	850
2	Ash content (%)	<1.01%	0.045
3	Calorific Value (Kj/kg)	41,800	42,000
4	Kinematic viscosity	<2.149	3.05
5	Cetane number	51	55
6	Flash point ^{0}C	40	50
7	Fire point ^{0}C	45	56
8	Carbon residue (%)	0.01%	0.20%
9	Sulphur content (%)	<0.002	<0.035
10	Pour point ^{0}C	-4	3-15

The flue gas is treated through scrubber and chemicals for neutralization. Since plastic waste is processed about 300-350 ^{0}C and there is no oxygen in the processing reactor, most of the toxic are burnt [power and Lawankar].

PERFORMANCE TESTING

The various performance parameters are taken into consideration to access the engine smooth operation and fuel optimisation such as brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature.

Brake Thermal Efficiency

Brake Thermal Efficiency is defined as break power of a heat engine which is a function of the thermal input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy.

Different researchers have investigated on the brake thermal efficiency of internal combustion engines and suggested many methods and modifications in the process to enhance it using plastic pyrolytic oil as fuel.

As discussed by Mani and Nagrajan [1], certain combustion parameters like delay period, ignition temperature and combustion chamber pressure which can augment the efficiency of compression ignition engine. They used a batch reactor following catalytic pyrolysis method and maintained a range of temperature of 300-400C under atmospheric pressure for 3-4 hrs. It yield 75% liquid hydrocarbon, which was a mixture of petrol, diesel and kerosene of 5%-10% residual coke. It was found that Brake thermal efficiency of plastic oil came closer to a value of diesel of 27.4% at a rated 75% rated power beyond which it started decreasing which may be due to high exhaust gas temperature.

Guntur.et.al [2], had taken an initiative to blend the waste plastic fuel with diesel in different ratio and found in variation in the performance used in same engine at different loads. It was found that the engine preformed better result at 50% of blending. Mechanical efficiency of engine increases with an increase in load under all operating conditions. Mechanical efficiency of diesel is 67.5% and with WPPO10- 69.3%, WPPO 30 - 70.34%, 71.49% with WPPO 50.

Kirubakaran.et.al [3], investigated on the performance and emission characteristics of a HCCI Engine running waste plastic oil. The engine modifications had been brought towards a good result in its mechanical efficiency. It was found that longer ignition delay of 0.5 CA of waste plastic than HCCI resulting rise in peak pressure by 5 bars inside cylinder which may be due to evaporation of waste plastic oil inside the cylinder by absorbing heat from combustion chamber. Cylinder pressure of HCCI is lower by 4 bar than waste plastic oil and injection timing controlled 23 degree before TDC.Rate of Heat release is maximum in waste plastic oil by 45 J/CA than HCCI which is due to longer delay period and high F/A ratio in waste plastic oil resulting increase in exhaust gas temperature.

Mani and Nagrajan [4], investigated the plastic fuel in diesel engine using Exhaust gas recirculation (EGR) techniques and demanded the better result found in its efficiency. The engine had been charged with 100% pyrolysed plastic oil with cooled EGR at different proportion. The effiency found increasing in EGR flow rate, it increases by 0.8% at 10% load and 1.1% at full load than waste plastic oil. This is due to larger replacement of air in combustion chamber by exhaust gas through EGR system and higher flow rate of EGR reduces average temperature in combustion chamber resulting reduction in brake thermal efficiency.

According to panda.et.al [5], efficiency had been found maximum of a value of 19.96 with 10% blending with WPO using kaolin at catalyst at full load. The efficiency became closer or slightly greater compared to diesel up to 80% load which might be due to higher calorific value of WPO-Diesel blend than diesel.

As per wongkhorsub and Chindaprasert [6], they had worked on efficiency of plastic oil and tyre oil in comparison to diesel had been tested on same Diesel engine at 1500 rpm. The maximum load production from plastic pyrolysis oil is lowest of 3064 W, tyre pyrolysis oil of 3282 W and diesel of 3500 W.

Pratoomyod and Laohalidanond [7], discussed about the performance of diesel engine using plastic oil at different ratio of blending with diesel. They had used a six cylinder 4 stroke diesel engine for that purpose. Brake Torque of the engine found decreasing when running from 1800rpm to 2000 which might be due to augmentation in mechanical losses and lower heating value. It reached to the peak value of 284.85 N at 1800 rpm, 25% blending and full load.

Brake Specific Fuel Consumption

According to Guntur and Kumar, BSFC decreases for all fuel blends up to part load of 80% and higher consumption was found at full load. Waste plastic fuel with ratio of WPPO10, WPPO30, and WPPO 50 at 1500rpm with loading of 0, 20,40,60,80 and 100% of rated power was observed. BSFC decreases for all fuel blends up to part load of 80% and higher consumption would occur at full load. Rate of Heat release is found maximum in waste plastic oil by 45 J/CA than HCCI which is due to longer delay period and high F/A ratio in waste plastic oil resulting increase in exhaust gas temperature.

According to Panda.et.al, it was found maximum in case of diesel without blending of a value of 0.385 kg/kwhr at full load and went on decreasing with increase in blending concentration of WPO with diesel. As the blended fuel was having high calorific value, the engine normally consumed less fuel.

C. Wongkhorsub and Chindaprasert had found that plastic pyrolysis oil offered lowest BSFC of 294 g/kwhr with maximum break power at 3064 W. The maximum load production from plastic pyrolysis oil was found a lowest value of 3064 W, tyre pyrolysis oil of 3282 W and diesel of 3500 W.

Pratoomyod and Laohalidanond had also agreed with other researchers taking different blending ratio of oil and getting better result. Experiment revealed that the blended fuels showed decreasing order of BSFC with increase speed of engine from 800 to 1500 rpm and after 1500 rpm, it went on increasing for all blends due to excess mechanical losses and incomplete combustion.

EMISSIONS

Mani.et.al, discussed about the combustion characteristics of DI diesel engine using waste plastic oil in a batch catalytic pyrolysis process. It was found that NOx emission increased in waste plastic oil operation due to high combustion temperature, oxygen concentration, and high heat release rate and residence time for reaction as compared to diesel. They investigated that Increase in Ignition delay of waste plastic oil that promoted premixed combustion by allowing more time for fuel to be injected prior to ignition could be another reason for increase of NOx emission.

Guntur and Ravikumar, approached differently to study the emission by feeding the engine with different blending ratio of plastic oil with diesel. The exhaust gas temperature was found higher which might be due to high heat release rate. Concentration of HC emission for WPPO-Diesel blend was marginally higher than diesel which might be due to some local spot of non-homogeneity in concentration of air fuel mixture found in the combustion chamber due to shortage of oxygen. Reason for higher CO emission may be due to incomplete combustion and higher rate of fuel consumption at higher load.

G. Kirubakaran.et.al, investigated on another dimension of emission. They claimed that NOx formation in waste plastic oil could be controlled by using HCCI at full load which might be due to higher cylinder inside temperature, lower oxygen concentration and longer residence time, higher heat release rate and higher combustion temperature. They also discussed about availability of premixed and homogenous charge inside engine and rapid flame propagation resulting lower smoke level in plastic oil. However at high load, white smoke was found emitted which may be due to non availability of sufficient oxygen and abnormal combustions.

Exhaust gas temperature found decreasing with increase in exhaust gas recirculation quantity which may be due to reduction in peak combustion temperature. Mani.et.al, introduced the technique of EGR that provided an extra quantity of exhaust gas to flow inside the combustion chamber. Due to less exhaust temperature and sufficient residence time to occur the reactions, NO_x emissions were quite regulated. HC emissions also regulated by optimizing injection timing at different EGR quantity and availability of excess oxygen.

As per panda.et.al, the emission of nitrogen oxides could be controlled by enriching the fuel air mixture. The reason may be due to the Composition of plastic fuel containing long carbon chain compound resulting longer ignition delay which would produce more NOx formations. The higher HC emissions in blend compared to diesel may be due to improper spray of fuel inside the combustion chamber. The gaseous HC remained unburnt along the cylinder wall. The other reason for it is due to presence of unsaturated HC in WPO, which was remained unbreakable during combustion process.

CONCLUSION

Many pioneer researchers step forward to work on area of plastic oil as an alternative fuel in DI diesel engine. Based on the review, it frames into picture that there is no significant power reduction in the engine performance on plastic pyrolysis oil blended with diesel up to 25% mixing.

1. Mechanical efficiency of pyrolytic plastic fuel with diesel found better result up to 50% blending.
2. Brake thermal efficiency of plastic fuel is found very close to diesel up to 75 % of rated power.
3. EGR up to 10% results better performance in its brake thermal efficiency.
4. The volumetric efficiency of plastic blended fuels is found decreasing as compared to diesel.
5. Emissions can be reduced using HCCI by 0.8% at full load.

Hence plastic fuel of required proportion blending can be used as a better alternative fuel for transportation.

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