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A review on use of Waste Plastic Oil as Alternative Fuel in CI Engine

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Abstract- *Increase in energy demand and depletion of energy resources have driven the researchers to seek ways to utilize waste product as fuel that could replace the fossil fuels. Conversion of waste to energy is one of the recent trends in minimizing not only waste disposal but also could be used as an alternative fuel for internal combustion engines. With the help of pyrolysis process waste plastic can be converted into high quality oil. The applications of plastic in industries are continuously increasing and the main issue associated with the plastic is disposal. In this context, waste plastics are currently receiving renewed interest. In this paper waste plastic oil, and blend of waste plastic oil and diesel is introduced as alternative fuel. In this paper, various operating parameter have been studied also this paper include emissions and performance characteristics while using waste plastic oil as fuel and contain comparative study with diesel emissions.*

Key words: Waste plastic oil, Pyrolysis, Diesel engine performance and emission

1. INTRODUCTION

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 the properties comparable to petroleum based fuels. Unlike rest of the world, India's demand for diesel fuel 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 fulfill energy security needs without sacrificing engine's operational performance. Waste to energy is the recent trend in the selection of alternative fuels. Fuel like alcohol, biodiesel, liquid fuel from plastic etc. are some of the alternative fuels for the internal combustion engines.

Plastics have woven their way into our daily lives and now pose a tremendous threat to the environment. Due to low cost of production, plastic consumption is increasing dramatically every year. In 2015 plastic production reached the 322 million tones worldwide [1]. At present waste plastic become a major component of municipal solid waste and amount of waste plastic is increasing day by day. The global production of polyethylene is around 80 million tons per year and main application in plastic bags, toys, oil containers, bottle sand wrapping foil for packaging [2].

Polyethylene is classified into two categories: low density polyethylene and high density polyethylene. Most of the plastics have very low degradation rate because of the molecular bonds of carbon, hydrogen and few other elements that make them very durable resulting in a very big environmental issue by land filling them. By using the plastic at the end of their life the issue of disposal can be reduced. However, waste plastics can become a source of enormous energy with the correct treatment. There are basically two recycling process: mechanical, chemical.

Chemical recycling or feed stock recycling can be used to treat significantly higher amount of waste plastics. Pyrolysis process is considered as a chemical recycling technique and it is a very promising technology for the waste plastic treatment [3-5]. Mechanical recycling is a technique that applies sorting, grinding, washing and extrusion and can be used to recycle single polymer waste, which represent the 15-20% of the total waste plastics [6]. Pyrolysis is a thermal degradation process that involves cracking of the complex organic molecules into smaller molecules and long hydrocarbon chains into shorter chains [7]. The process takes place in the absence of oxygen at elevated temperatures. The major products from the pyrolysis process are in liquid, gaseous and solid from while the amount of each product mainly depends on the feed stock composition and the pyrolysis process parameter such as temperature, residence time, heating rate and catalyst [8, 9].

M. F. Ali reported that the high yields of liquid fuels in the boiling range 100-480 C and gases were obtained along with a small amount of heavy oils and insoluble material such as gums and coke. The result obtained on the co-processing of polypropylene with coal and petroleum residues are very encouraging as this method appears to be quite feasible to convert plastic material into liquefied coal products and to upgrade the petroleum residues and waste plastics [9].

According to the literature review, the EVA (ethylene-vinyl acetate) pyrolysis has not been investigated in depth and the basic properties of the produced oil has not been reported yet [10-12]. On the other hand, the pyrolysis of polyethylene has been studied by various authors and the oil composition results suggest that is promising fuel for power and heat generation [9, 13].

Miskolczi investigated the pyrolysis of real waste plastics in a pilot scale horizontal tube reactor at 520 C temperatures in the presence and absence of ZSM-5 catalyst. It was found that the yields of gases, gasoline and light oil could be increased in the presence of catalyst. They also concluded that the plastic waste could be converted into gasoline and light oil with yields of 20-48% and 17-36% respectively depending on the used parameters [14].

Internal combustion engines and specially diesel engines are preferable for power generation from alternative fuels due to their high efficiency, excellent durability, less demanding exhaust emission regulations and fuel quality [15]. Gungor et. al. Conducted a research on a four-cylinder diesel engine using the oil that derived from the pyrolysis of high density polyethylene blended with diesel at 5% blend ratio. The investigations on HDPE showed lower brake thermal efficiency and cetane number and higher carbon dioxide and nitrogen emissions than diesel operation [16].

F. Murphy [18] from the recent literature, it is evident that the process of converting waste plastic to reusable oil is a current research topic. Hence in this paper, preparation of blends of diesel with varying proportions of waste plastic oil produced from the thermal pyrolysis and the analysis of viscosity and density of these blends is presented. The feasibility of the waste plastic oils derived from PVC plastics as an alternative fuel for transportation is also checked by conducting performance test on single cylinder Kilosker diesel engine equipped with electrical loading at 50% of the engine maximum load i.e. at 3.7 Kw.

Finally, Kumar et. al. investigated the effect of fuelling a twin cylinder diesel engine with HDPE oil with blends up to 40% with diesel. The result showed higher nitrogen oxides, unburned hydrocarbons and carbon monoxide emission and lower carbon dioxide and brake thermal efficiency than diesel engine [17].

2. COVERSION PROCESS AND FUEL PROPERTIES

LDPE (low density polyethylene) and EVA (ethylene-vinyl acetate) were used as feed stocks and converted into high quality oils via the fast pyrolysis process. The schematic layout of the pyrolysis plant that was used is shown in Fig. 1.

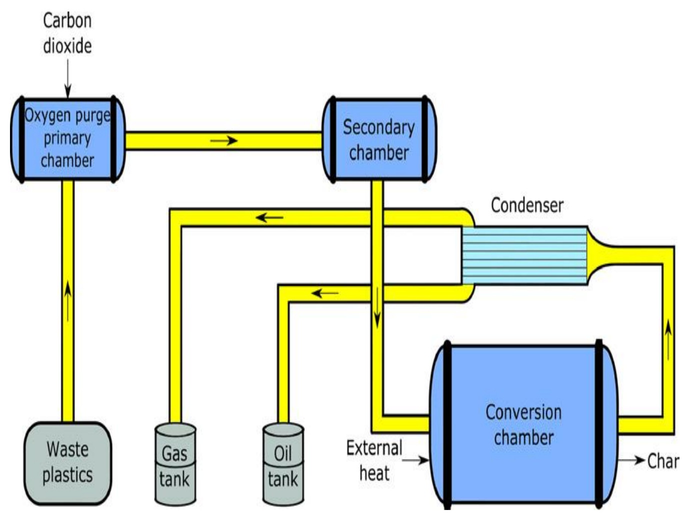

Fig. 1 schematic layout of the pyrolysis process [19]

Pyrolysis technology is thermal degradation process in the absence of oxygen. Plastic waste is treated in a cylindrical reactor at temperature of 300-350 C . The plastic waste is gently cracked by adding catalyst and the gases are condensed in a series of condensers to give a low sulphur content distillate. All this happens continuously to convert the waste plastics into fuel that can be used for generators. The catalyst used in this system will prevent formation of all the dioxins and furans. All the gases from this process are treated before it is let out in atmosphere. The flue gas is treated through scrubbers and water/ chemical treatment for neutralization. The non-condensable gas goes through water before it is used for burning. Since the plastics waste is processed about 300-350 C and there is no oxygen in the processing reactor, most of the toxics are burnt. However, the gas can be used in dual fuel diesel-generator set for generation of electricity.

Table 1. Comparison of fuel properties from waste plastic Oil and diesel fuel (20)

Property	Waste plastic oil	Diesel
Density (at 30°C)	0.8355	0.840
Ash content,(%)	0.00023	0.045
Gross calorific value	44.340	46.500
Kinematic viscosity	2.52	2.0
Cetane number	51	55
Flash point, (°C)	42	50
Fire point, (°C)	45	56
Carbone residus,(%)	82.49	26
Sulphur content,(%)	0.030	0.045

3. PERFORMANCE CHARACTERSTICS

The various performance parameters such as brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature under study is summarized as follows

3.1 Brake specific fuel consumption

An experimental study on diesel engine with blends of diesel-plastic pyrolysis oil indicates that BSFC was found to increase with load for WPPO 50, WPPO 70 and diesel fuel. As the load increases, BSFC decreases for all fuel blends. At full load, WPPO blends show the specific fuel consumption is higher than diesel. The main reason for this could be that percent increase in brake power due to relatively less portion of the heat losses at higher loads [21]. The brake specific fuel consumption for the waste plastic oil varies from 0.574 g/kWh at no load to 10.297 g/kWh at full load for standard injection timing, and it varies from .514 g/kWh at no load to .235 g/kWh at full load for retarded injection timing [22].

3.2 Exhaust gas temperature

An experimental study on diesel and waste plastic blend in CI engine proved that with increasing load more fuel is burnt to meet power requirement that's why exhaust gas temperature increases with load. from the experimental study it observed that in the case of pure plastic oil the exhaust gas temperature varies from 240 C at low load to 450 C at full load. In CI engine while increasing the amount of plastic oil in the blend the exhaust gas temperature continuously goes on increasing [20].

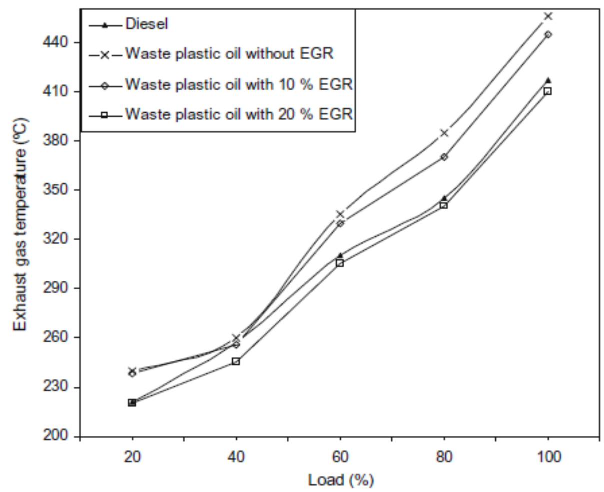

Fig. 2 variation of exhaust gas temperature with load for various EGR [24]

From experimental study it is clear that the exhaust gas temperature increases with EGR [24].

3.3 Brake thermal efficiency

The experimental study on a single cylinder, four-stroke, air cooled DI diesel engine with waste plastic oil [20], results the thermal efficiency is 28.2% at rated power for diesel and for the waste plastic oil it is 27.4%. Further the brake thermal efficiency of the waste plastic oil is closer to diesel up to 75% of rated power, beyond which it starts decreasing. At full load, the efficiency is higher for diesel fuel. This is due to the fact that at full load, the exhaust gas temperature and the heat release rate are marginally higher for waste plastic oil compared to diesel. An experimental study on waste plastic oil with varying injection timing results the thermal efficiency is 28.2% at full load for standard injection timing and 32.25% for the retarded injection timing of the waste plastic oil. Retardation of injection timing leads to fast start of combustion and combustion continues in the power stroke. This results in smaller peak heat release rate and increases effective pressure to do work. Consequently, the work output is high for retarded injection timing and therefore the brake thermal efficiency increases as the injection timing retarded [23].

4. EMISSION CHARACTERSTICS

Internal combustion engine emission have been major contributor to air pollution regulated pollutants are carbon monoxide, NOx and unburnt fuel or partly oxidized HC. Which are summarized as follows

4.1 Carbon mono-oxide (CO) and carbon dioxide emission

Generally, CI engine lean mixture is used, and hence the CO emission would be low. CO emission is harmful for human being so it must be controlled. Reason of CO emission is incomplete combustion of hydrocarbon fuel. The experiment performed on a single cylinder, four stroke, air cooled diesel engine with waste plastic oil. For the diesel engine CO concentration varies from 14.14g/kWh to 5.75g/kWh at 25% of rated power and for waste plastic oil it varies from 18.51g/kWh to 6.19g/kWh. Hence it concluded that the CO emission is higher for waste plastic oil. The reduced cylinder temperature is the cause of incomplete combustion [20].

Waste plastic oil with exhaust gas recirculation in direct injection diesel engine indicate that the concentration of CO_2 in the the exhaust is continuously decreasing with increasing amount of EGR [24].

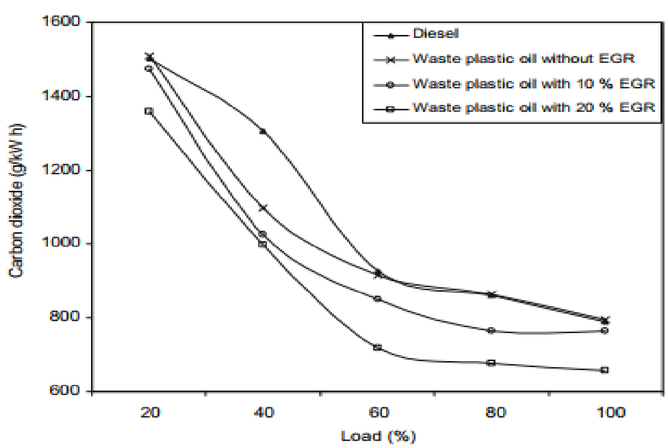

Fig.3 Variation of carbon dioxide with load for various EGR [24]

4.2 Nitrogen oxide emission

An experimental study on waste plastic oil and diesel fuel blends in compression ignition engine indicate that, the concentration of NOx varies from 12.15 g/kWh to 7.61 g/kWh for diesel fuel with increasing load and from 14.68 g/kWh to 8.23 g/kWh for WPO with increasing load. For WPO10, it varies from 12.16 g/kWh to 7.75 g/kWh with load. It was also observed that with increasing amount of waste plastic oil in blend the amount of NOx emission goes on increasing. The reason of higher NOx formation is higher heat release in case of waste plastic oil. Because the fuel with ring structure has a higher adiabatic flame temperature which results in higher heat release. The in-cylinder temperature increases with increasing amount of waste plastic oil due to higher heat release and this is the reason for NOx formation [23].

The experimental work on waste plastic oil with exhaust gas recirculation in direct injection diesel engine indicate that NOx emission continuously decreasing with increasing load and the NOx emission continuously decreasing with increasing amount of EGR. The reason of decrement in NOx concentration is presence of inert gas in EGR. These gases absorb heat release by combustion due to which in cylinder temperature reduces and also it replaces the oxygen in the chamber [24].

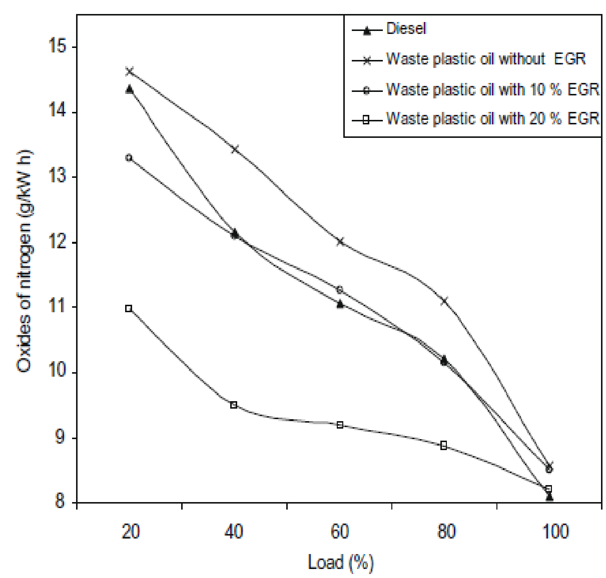

Fig.4 variation of NOx with load for various % of EGR [24]

4.3 Unburned hydrocarbon

Hydrocarbon means organic compounds in the gaseous state and solid hydrocarbon are part of the particulate matter. Unburned hydrocarbon produced due to incomplete combustion. At higher load in CI engine UHC become a serious issue. At light load fuel quantity is less so less fuel impinges on surface, but because of poor fuel distribution, low exhaust temperature and lean air fuel mixture regions may survive to escape into exhaust [25].

An experimental study on waste plastic shows that concentration of UHC of waste plastic is higher than diesel. Due to fumigation rate and non-availability of oxygen the concentration of unburned hydrocarbon is higher in waste plastic oil [20].

An experiment shows that with increasing amount of EGR concentration of unburned hydrocarbon goes on increasing. The formation of NOx is highly dependent on in cylinder temperature, the oxygen concentration and residence time for the reaction to take place [24].

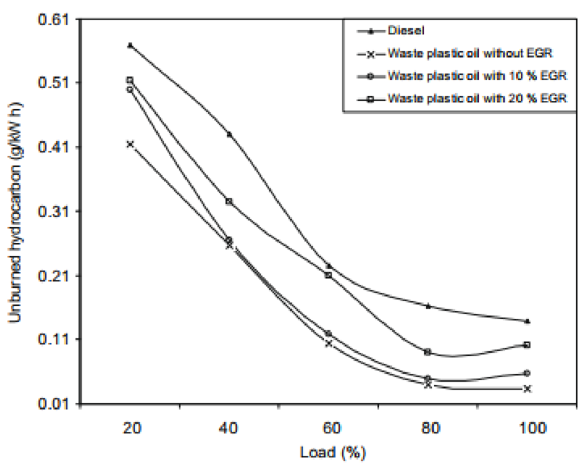

Fig. 5 Variation of UHC with load for various % of EGR [24]

5. CONCLUSION

From the experimental studies it is clear that the waste plastic oil is a good alternative fuel for the diesel engine and for the future transportation vehicle it can be used. Flowing conclusions are derived from the study

- From the study it is also concluded that engine was able to run with only plastic oil but emissions are higher as compared to blend of waste plastic oil and diesel.
- With the retardation of injection timing the brake thermal efficiency of waste plastic oil is higher.
- With increasing % of EGR brake thermal efficiency is decreases.
- Engine fuelled with waste plastic oil exhibits higher thermal efficiency upto 75% of rated power.
- For the waste plastic oil exhaust temperature is higher than diesel due to high heat release rate. At the full load fuel consumption is higher for WPO blend.
- Waste plastic oil emits 15% higher unburned hydrocarbon than diesel fuel and CO emission is 5% more than diesel.
- The CO2 and NOx concentrations decrease with increase % EGR.

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