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Catalytic degradation of waste PVC into liquid fuel using baco$_3$ as catalyst and its blending properties with diesel fuel

Elackiya Manickaraja[1], Senthilkumar Tamilkolundu[2]

[1]Department of Mechanical Engineering,Anna university(BITcampus)Tiruchirappalli, India

[2]Department of Mechanical Engineering,Anna university(BIT campus), Tiruchirappalli, India

ABSTRACT: *This paper aims at recycling the available waste polyvinyl chloride plastics and utilizing it effectively for transportation purposes. The collected waste PVC's are made to undergo thermal pyrolysis process which is being maintained at temperature of 450°c in the absence of oxygen and waste plastic oil is extracted. This extracted oil is then blended with different proportions of diesel and their properties were compared with diesel. These sampled fuels could be made feasible for transportation purposes. Plastics which are considered as hazardous to environment pose severe threat to the living beings. The oil collected by this process was found to be less when compared with the oil which is being collected using the catalyst* $BaCO_3$ *.The percentage amount of oil extracted by using the catalyst was found to be 20% higher than that of the oil extracted without using catalyst. In the catalytic pyrolysis the increase in the quantity of catalyst increases the amount of the petroleum products obtained and reduces the time required. In order to reduce the waste plastics and prevent the environmental damage plastic recycling is being done.*

KEYWORDS: *plastic recycling, thermal pyrolysis, catalytic pyrolysis, petroleum products.*

I. Introduction

The rapid increase in population has led to the complete utilization of available energy. This led to dependence on secondary resources like coal, biomass, tidal etc., in order to satisfy the thirst of energy dependence many alternative methods have been developed. Simultaneously, optimum utilization of energy,recycling of waste products will proportionally help to satisfy the energy dependence. One such efficient method of obtaining energy is plastic recycling.To satisfy the increasing population dependence on transportation, plastic oil is extracted and added along with petroleum products.Waste plastics create a very serious environmental challenge because of their huge quantities and their disposal problems. Plastics are now indispensable materials and their applications in the industrial field are continually increasing. Plastics are produced from petroleum derivatives and are composed primarily of hydrocarbons but also contain additives such as antioxidants, colorants, and other stabilizers. However, when plastic products are used and discarded, these additives are undesirable from an environmental point of view. Plastics are not presently biodegradable and are extremely troublesome components for land filling. Their destruction by incineration poses serious air pollution problems due to the release of airborne particles and carbon dioxide into the atmosphere. There are different methods of recycling the waste PVC like gasification, pyrolysis, depolymerisation. Recycling has become a major response to the environmental challenges facing the plastics industry.Plastics have gained their attention due to their light weight, Resistant to rust and corrosion,Transparent and freely colorable and less cost.

PawarHarshal,et.al[1] reviewed the Waste plastic pyrolysis oil alternative fuel and obtained various parameters for better understanding of operating conditions and constrains for waste plastic pyrolysis.

T. Senthilkumar, et.al[2] Evaluated the blend of Waste Plastic oil-Diesel fuel as alternative fuel for transportation and inferred that mixing of waste plastic oil with diesel from thermal pyrolysis and analysed by FTIR spectrum and their feasibility is checked by conducting test in single cylinder Kirlosker diesel engine with 50% maximum load.

M. RasulJan,et.al[3] observed that the high density polyethylene degraded thermally while using the catalyst as their promoter and gave maximum yield.

V.I. Narayanan,et.al[4] studied experimentally on the Performance of CI Diesel engine using Plastic Pyrolysis oil blends with pure diesel and observed the overall performance of the biodiesel in the CI diesel engine and proved with graphical representation.

D.P. Deshpande,et.al[5] obtained that a detailed experimental procedure for degradation of plastics through thermal pyrolysis in the Petro chemical feed stock from plastic wastes.

A.K. Panda, et.al[6] obtained that production of liquid fuel from plastic waste would be a better alternative as the calorific value of the plastics is comparable to that of fuels, around 40MJ/kg. This option also reduces waste and conserves natural resources. It was also mentioned that mechanical recycling of plastic wastes is widely adopted method by different countries and the catalytic pyrolysis of plastic to fuel is gradually gaining momentum and being adopted in different countries recently due to its efficiency over other process in all respects.

J.Aguado,et.al[7] have obtained that various methods of recycling the waste feedstock and plastics and summarized the current scenario of plastic residue in European countries.

J. Walendziewski[8] inferred that in thermal pyrolysis method the first series of polymer cracking experiments was carried out in a glass reactor in a temperature range 350-420°C, the second one in autoclaves under hydrogen pressure (~3-5MPa) in temperature range 380-440°C.

M.N. Siddiqui, et. al[9] described the catalytic processing of waste plastic and petroleum residues into liquid fuel been explored due to the effects of various conditions such as catalyst type, amount of catalyst, reaction time, pressure and temperature on the product distribution of co processing of waste plastic.

M.F. Ali ,et al[10] reported the catalytic coprocessing of coal and petroleum residues with waste plastics to produce transportation fuels obtained 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.

N.Miskolczi[11], analysed the Fuels by Pyrolysis of waste plastics from agricultural and packaging sectors in a pilot scale reactor and found that the pyrolysis of real waste plastics (high-density polyethylene and polypropylene) in a pilot scale horizontal tube reactor at 520 °C temperature in the presence and absence of ZSM-5 catalyst.

II. Thermal Pyrolysis Process for Conversion of Waste PVC Into Liquid Fuel

Pyrolysis technology is thermal degradation process in the absence of oxygen. Plastic waste is treated in a cylindrical reactor at temperature of 300ºC – 350ºC. 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 (Benzene ring). 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 300ºC - 350ºC 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. The process for conversion of waste PVC into liquid products is shown below in figure 1

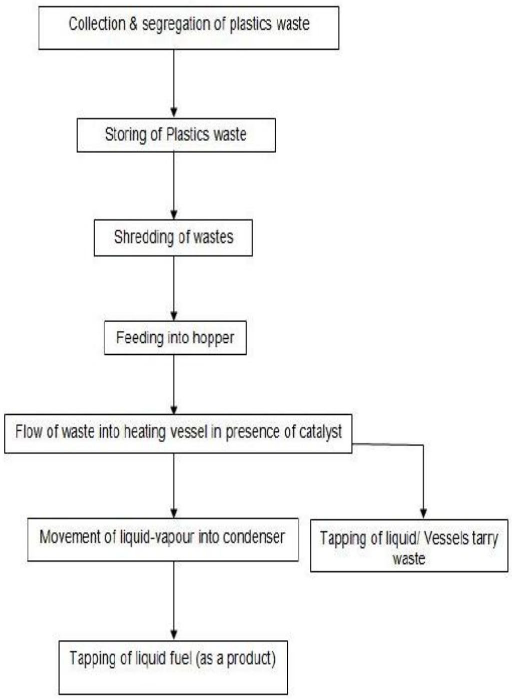

Figure 1 Flow chart of pyrolysis process.

III. Experiment

The equipments required for the process of oil extraction are listed below.

1) Raw plastics (waste PVC plastics).
2) Catalyst.
3) Thermal reactor.
4) Cut off regulator.
5) Thermocouple.
6) Condenser.
7) Submersible pump.
8) Collector.
9) Weight balance.

Figure 2 Experimental set up

The raw material, crushed wastes PVC plastics is used to fill the electrical heater. The wall of the thermal reactor is connected with thermocouple. The thermocouple .the thermocouple is connected with cut-off regulator. Top part of the reactor connected with condenser. The condenser has two internal and two external ports , Water inlet and water outlet ports. In that water inlet port water taken into the condenser by using submersible pump. Water is used to circulate inside the condenser tube .then the water is expelled through the outlet port and the water falls into the bucket. The condenser tube also has two external ports for the vapor to flow through it,Vapour inlet and vapour outlet ports. The vapor which comes out from the reactor is allowed to flow into the inlet port of the condenser. Vapor which is cooled inside the condenser by circulating water is collected in the collector through the outlet port.

The cut-off regulator is set to the temperature of around 400˚c. The waste PVC plastics melt inside the thermal reactor. After 10 mins, the reactor temperature will reach a temperature range of 370˚c. since the cut-off regulator was set to this maximum temperature , the current supply will be stopped . At that mean time the water is circulated to the condenser by using the submersible pump. The vapor coming from the thermal reactor is condensed by the circulating water, and hence the vapor is transformed to oil in the condenser tube . The condensed oil is then collected in the beaker kept below the vapor outlet. It is observed from the study that 130 g of waste polyvinyl chloride (PVC)plastics and 1% of catalysts namely $BaCO_3$ which yield about 20-25 ml of PVC oil. The entire process was completed in 20 mins. The waste sludge obtained is found to be light in nature . It is observed that sludge once obtained cannot be reused and even if it is recycled.Usage of $MgCO_3$ as catalyst cou;d yield 30% of waste plastic oil.

IV. Blending

The extracted oil is blended with different proportions of diesel using Magnetic stirrer. The proportions blended are 5%, 15%,25%. The properties of the different blends are as follows,

Table 1 Property Analysis

Properties	Diesel	Parent oil	5% WPO	15% WPO	25% WPO
Density (kg/m^3)	840	830	825	835	845
Specific gravity	0.840	0.830	0.825	0.835	0.845
Flash point ˚c	50	40	39	42	45
Fire point ˚c	56	44	48	51	55
Kinematic viscocity at 30˚c cst	2.999	6.364	1.52	4.431	3.236

V. Results and Discussion

The following results were obtained from the above experiment,

PHYSICAL OBSERVATION

The physical appearance of the source PVC before and after the thermal pyrolysis is shown in the following photograph figure3

Figure3 Physical observation of the PVC

The percentage oil collected by using the catalyst was found to be higher when compared with extraction of oil without the catalyst.

This is graphically proved in the graph. The graph is shown in figure4

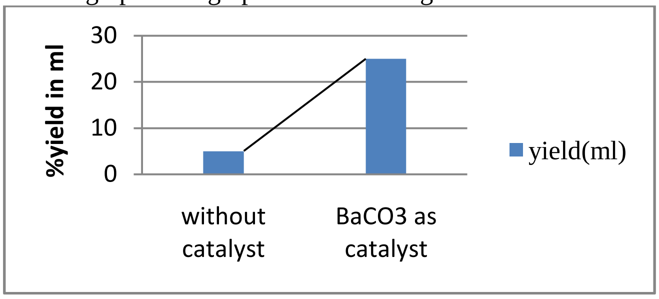

Figure 4 Comparison of the yield

The above graph is drawn with and without catalyst on X-axis and their % yield is drawn on the Y-axis.It is obtained from the above graph that plastic oil yield increases by the use of catalyst . The use of catalyst is to increase the oil yield and to reduce the time of the reaction.

Comparison of the Property Test with Diesel Oil

The properties like flash point, fire point density, kinematic viscosity were determined for both the plastic oil and diesel. The values were plotted with diesel and plastic oil as X-axis and temperature range values on Y-axis. The result shows that the properties of plastic oil approximately equals with that of the diesel.
Property analysis test on flash and fire point in diesel and waste plastic oil is shown in the figure 5

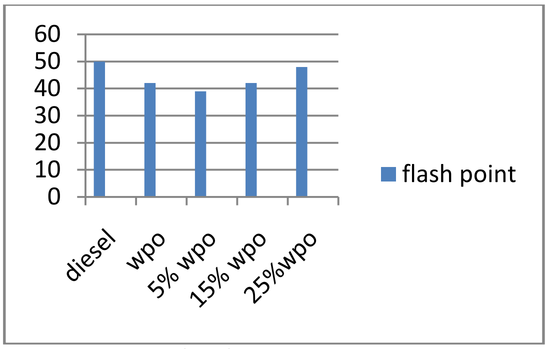

Figure 5 comparison of the flash point with diesel and WPO blends

It is obtained from the above graph that flash and fire point of the plastic oil is found to equals with that of the diesel with oil on X-axis and the flash and fire point on Y-axis.

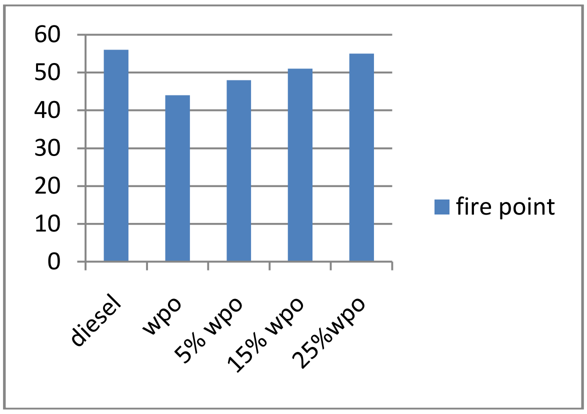

Figure 6comparison of the firepoint with diesel and WPO blends

Graph showing fire point variation on diesel and waste plastic oil is in shown the figure 7

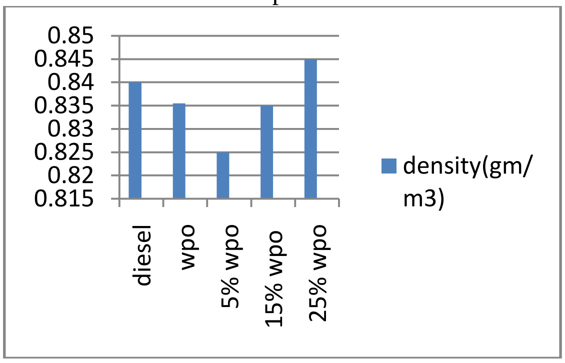

Figure 7 comparision of density with diesel and WPO blends

It is obtained from the above graph that the density of the plastic oil is found to be equal with that of the diesel. Graph showing variation in kinematic viscosity in diesel and waste plastic oil is shown in the fig 8

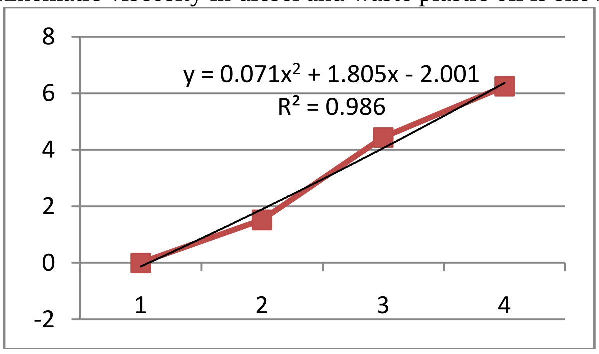

Figure 8 Variations in kinematic viscosity

The graph obtained with by plotting kinematic viscosity on y-axis and oil in x-axis predicts that the variation of the plastic oil approximately equals with that of the diesel.

VI. Conclusion

The following results were obtained from this experimental work,

- The yield obtained by this process was found to be 20% higher than that of the yield obtained without catalyst.
- The property test results were found to be approximately equals with that of the diesel fuel.
- The best blend for engine test was found to be 25% blend.

Hence , it can be concluded that the oil derived from waste PVC could be used as an alternative fuel for transportation engines.

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