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Investigation of Chemical Properties of Pyrolysis Oil Extracted from Waste Plastics

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Abstract--Energy shortages and rapid increase in its demand are amongst the major problems facing the world today. In response to the rapid depletion of fossils fuels, other alternative energy sources have been explored. One of the methods of generating energy is converting plastics into usable fuel. Two major problems facing the world today prompting to pyrolysis are disposal of plastic waste due to their non -biodegradable nature and depletion of fossil fuels as a result of the continuously rising demand. The feedstock for the pyrolysis plant was selected to be Polyethylene Terephthalate (PET) in the form of flakes ranging from 8 – 12 mm and was supplied by PETRECO.

The conversion of plastic to high quality pyrolysis oil through pyrolysis process is highly advisable as the oil produced has high calorific value than that of commercial fuel.

Keywords:--Plastic Waste, Pyrolysis, Fuel Production, Paraffin

I. INTRODUCTION

Plastics are organic compounds having long chained hydrocarbon synthesized from petroleum products. Because of its own special features plastic had acquired wide popularity in short time. Plastic production and consumption rate increased exponentially due to its low cost, non-degradable nature, easy availability and management, wide range of usage and application. According to the estimate given by APME (Association of Plastic Manufacturers Europe), the global production of plastic has crossed 280 million tons in 2011 and it is increasing exponentially [1]. The increasing demand of plastic products also increases the accumulation of plastic waste that endangers the environment because of their disposal problems [2].The rising plastics demand also led to the exhaustion of non-renewable crude oil as plastics are petroleum-based material. To minimize the adverse environmental impacts of plastic waste, many organizations are implemented with plastic waste management systems, for control/reduction of plastic waste formation.

The term pyrolysis describes the decomposition of polymers (Ex:-resins, cellulose) gaseous hydrocarbons (Ex: -acetylene), hydrocarbon-rich oils and various others organic materials such as petroleum by-products, inducedsolely by heat pyrolysis.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, dimethyl ether, and biogas. On the other hand, appropriate waste management strategy 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 potential materials in waste which are plastic, biomass and rubber tire to be oil. Pyrolysis process becomes an option of waste-to-energy technology to deliver bio-fuel to replace fossil fuel. Waste plastic and waste tire are investigated in this research as they are the available technology[3]. The advantage of the pyrolysis process is its ability to handle un-sort 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.

Economic growth and changing consumption and production patterns are resulting into rapid increase in generation of waste plastics in the world. For more than 50 years the global production of plastic has continued to rise.

Approximately 10–20 million tons of plastic end up in the oceans each year. A recent study conservatively estimated that 5.25 trillion plastic particles weighing a total of 268,940 tons are currently floating in the world's oceans. And since plastic being a non-biodegradable material it remains into the soil, thereby polluting the environment.

Pyrolysis is an alternative thermolytic technique used to convert biomass into fuel. Pyrolysis or thermolysis is in essence of an irreversible thermo chemical treatment process of complex solid or fluid chemical substances at elevated

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temperature, in an inert or oxygen-free atmosphere involves chemical change of chemical composition & physical phase. (Irreversible process) does not involve reactions with oxygen water or any other reagents in practice. It is not possible to achieve a completely oxygen-free atmosphere because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs. The plastic is pyrolyzed at 600^0-700^0 C & The pyrolysis gases are condensed in a series of condensers to give a low sulphur content distillate. On the other hand, appropriate waste management strategy is another important aspect of sustainable development since waste problem is concerned in every city**[15, 16]**. As we know that both Plastics and Petroleum derived fuels are Hydrocarbons that contain the elements of Carbon & Hydrogen. Pyrolysis process becomes an option of waste-to-energy technology to deliver bio-fuel to replace fossil fuel. The advantage of the pyrolysis process is its ability to handle un sort and dirty plastic. The pre-treatment of the material is easy. Plastic is needed to be sorted and dried. Pyrolysis is also no toxic or non-environmental harmful emission unlike incineration.

➔ Availability :- Waste recycled plastics:

- Polypropylene (PP):-food containers, appliances, car fenders (bumpers), plastic pressure pipe systems.
- Polystyrene (PS):-packing foam, food containers, disposable cups, plates, cutlery, CD & cassette boxes.
- High impact polystyrene (HIPS):-fridge liners, food packaging, vending cups.
- Acrylonitrile butadiene styrene (ABS):-electronic equipment's cases (Example: - computer monitors, printer, keyboards) , drainage pipe.
- Polyethylene terephthalate (PET):-carbonated drinks bottles, jars , plastic film , microwavable packing.
- Polyester (PES):-fibre, textiles.
- Polyamides (PA) (Nylons):-fibres, toothbrush bristles, fishing line, under the hood car engine moulding.
- Polyvinyl chloride (PA) (Nylon):-plumbing pipes & guttering, shower curtains, window frames, flooring.
- Polyurethanes (PU) :-cushioning foams , thermal insulation foams , surface coating , printings rollers

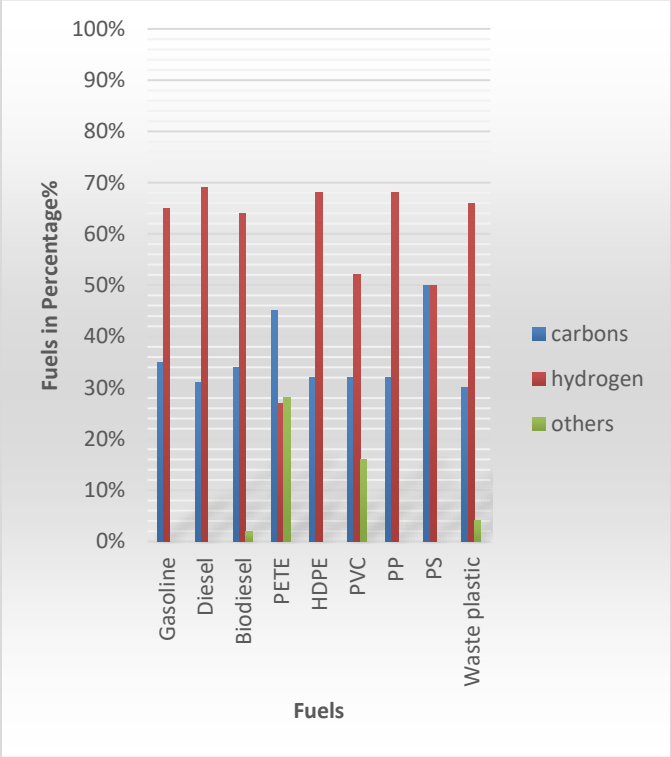
CHARACTERISTICS OF PLASTICS AND OIL PRODUCTS:-

Before looking at the process options for the conversion of plastic into oil Products, it is worth considering the characteristics of these two materials, to identify where Similarities exist, and the basic methods of conversion. The principal similarities are that they are made mostly of carbon and hydrogen, and that they are made of molecules that are formed in chains of carbon atoms.

Crude oil is a complex mixture of hydrocarbons, which are separated, and Purified by distillation and other processes at an oil refinery. The majority of the crude oil is used for the production of fuels for transportation, heating and power generation. These oil products are not single components, but are a blend of components used to meet the relevant fuel specifications in the most economic manner, given the composition of the crude oil and the configuration of the oil refinery. These components have a wide range of chain lengths: gasoline has compounds with a chain length of between three and 10 carbon atoms, and diesel has compounds with a chain length of between five and 18 carbon atoms, but both contain only hydrogen and carbon.

Plastic is a generic term for a wide range of polymers produced using highly refined fractions of crude oil, or chemicals derived from crude oil, known as monomers**[14]**. Polymers are formed by the reaction of these monomers, which results in chain lengths of tens or hundreds of thousands of carbon atoms**[12]**. Some polymers also contain oxygen (e.g. polyethylene terephthalate (PET)), whereas others contain chlorine (polyvinyl chloride (PVC))**[13]**. It is worth noting that only a small proportion (< 5%) of the crude oil processed in the world is used to produce the monomers (e.g.ethane, propene) used in the manufacture of polymers (e.g. polyethene, polypropylene).

Percentage of carbon & Hydrogen in different fuels



Experimental work:-

Materials:-Recycled plastics like polyethylene (PE), polypropylene (PP), polystyrene (PS), high density polyethylene (HDPE), low density polyethylene (LDPE).

Usually they are manufactured in the form of plastic bags, saline bottles, plastic tools, chairs and other components which we usually come across in our day to day

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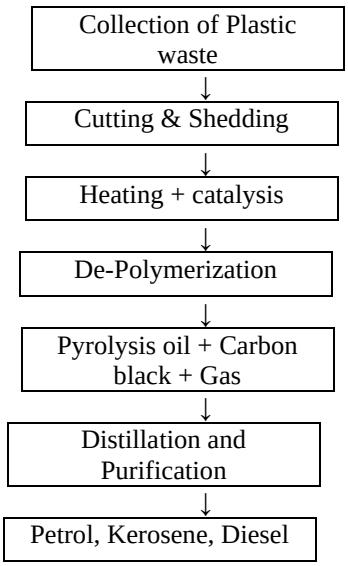
life. These plastics could be collected or usually purchased at Rs.10 to 15/kg after being shredded and washed properly.

Plastic for fuel production

Recycling of plastic is difficult and costly because of the restrictions on contamination of water and labor intensive segregation of different plastics before recycle which is labor intensive **[4].** Clearly transparent plastics can be easily dyed to transform into new products, have greater flexibility and are mostly desirable by the manufacturers **[5, 6].** Recycling plastic is energy intensive too. As there is an alarming depletion of energy sources, means of energy recovery from plastic waste is a good option. Pyrolysis is a suitable method for energy recovery from plastic waste and is one of the finest techniques for the conversion of mass to energy with liquid and gaseous products with high energy values **[6].** Figure 1represents the processes involved in the pyrolysis of plastic.



Flow chart of plastic pyrolysis process

Pyrolysis or thermal cracking involves thermal degradation of long chain polymer molecules into less complex smaller molecules. The process takes place in the absence of oxygen at increased pressure and temperature for a short duration.
Pyrolysis process is proposed by many researchers since the process is able to produce large quantity of liquid oil up to 80 wt% at temperatures around 500°C**[8]**. The process parameters can be altered to generate products based on personal preferences. Hence pyrolysis is often referred as a flexible process. The liquid oil produced is of high quality as it cans be used in multiple applications without any up gradation or treatment **[7]**. The gaseous fuel produced as the byproduct of pyrolysis, can be reused to compensate the energy requirement of the pyrolysis plants the gaseous fuel produced is of high calorific value **[9]**. Pyrolysis is mostly employed over common recycling processes since handling is much easier and flexible. Moreover, pyrolysis does not require intense sorting process and hence it is less labor intensive process. Many published research papers are available on the potential of pyrolysis processes on various types of plastics for liquid fuel production. The present review comprehends the properties and use of various categories of plastics and description of pyrolysis process for fuel production for each category.

REACTOR

Fig Typical Feed for process

→It is a heart of out process, it is a air tight cylinder, it has a capacity of 15.3 KG , this capacity is used to feed plastic in it, it has exhaust hole at the top through which oil vapours are exhausted , this oil vapour is passed to condenser and hence pyrolysis oil is produced.

Reactor is a closed chamber which is used to burn the waste plastics in the absence of oxygen, which has only one opening at the top for the flow of exhaust gases to condenser.

FIRING CHAMBER

→It has a capacity of 200 LTR, it consists of all other equipment's like burners, reactors (LPG cylinder) connections and sand, it has manholes for air circulation and for burner connections.

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BURNERS:

→These burners are 1 feet long and 3 in number, which are connected to tank, where it is used to heat the reactor at a temperature around 700^0C.

CONDENSER: -

→ Condenser is a device or unit used to condense a gaseous substance into a liquid state through cooling; here water-cooled condenser is used to condense the vapor.

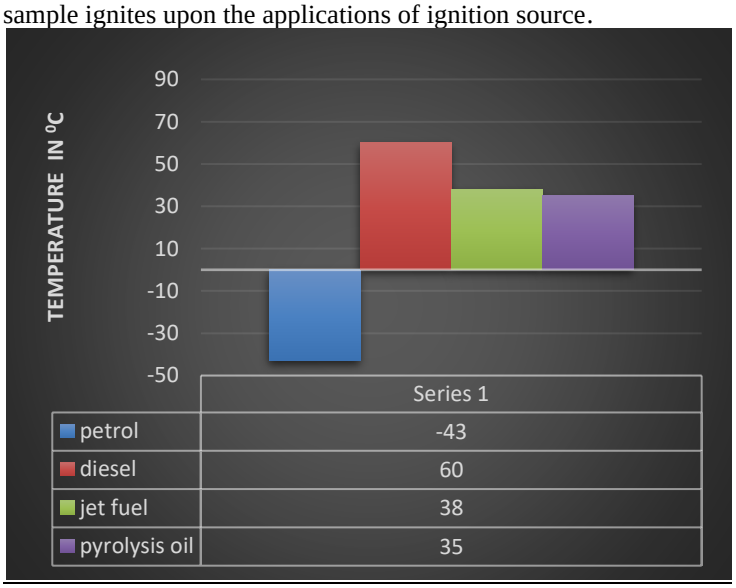
Connecting tube: -

→Connecting tube provides LPG gas passage from the cylinder to the chamber; in this process copper coil tubes are used.

Result and discussion:-

Flash Point-The flash point is the lowest temperature at which a volatile substance evaporate to form an ignitable mixture which air in the presence of an igneous source an continues burning after the trigger source is removed.
The instrument which is used to identify the flash point is **Abel's flash** point.

The automatic Abel closed – cup tester measures the flash points, the lowest temperature at which the vapor of the sample ignites upon the applications of ignition source.



Flash Point of different Fuels

Viscosity-Viscosity is a measure of a fluids resistance to flow. where viscometer is an instrument to measure the viscosity of the fluid. An instrument which is used to calculate viscosity is **Say bolt and Redwood Viscometer.**

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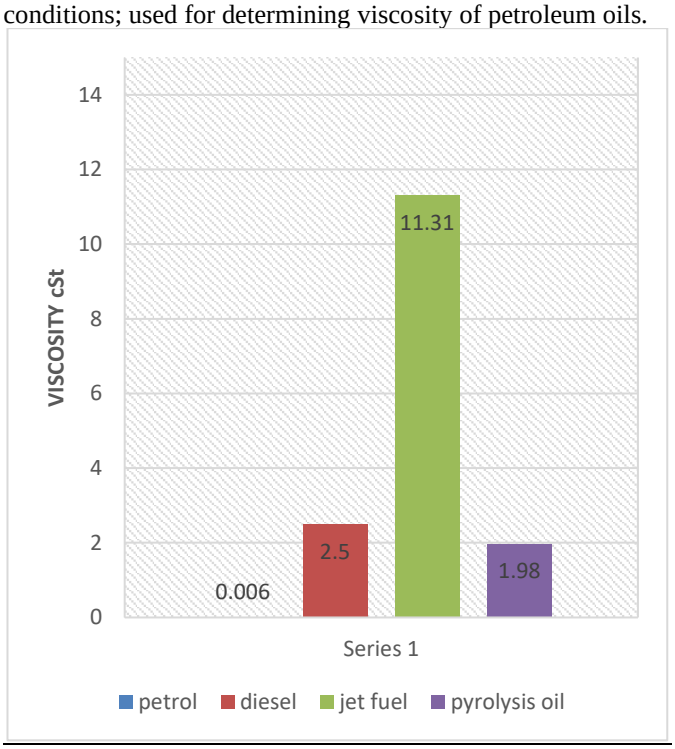
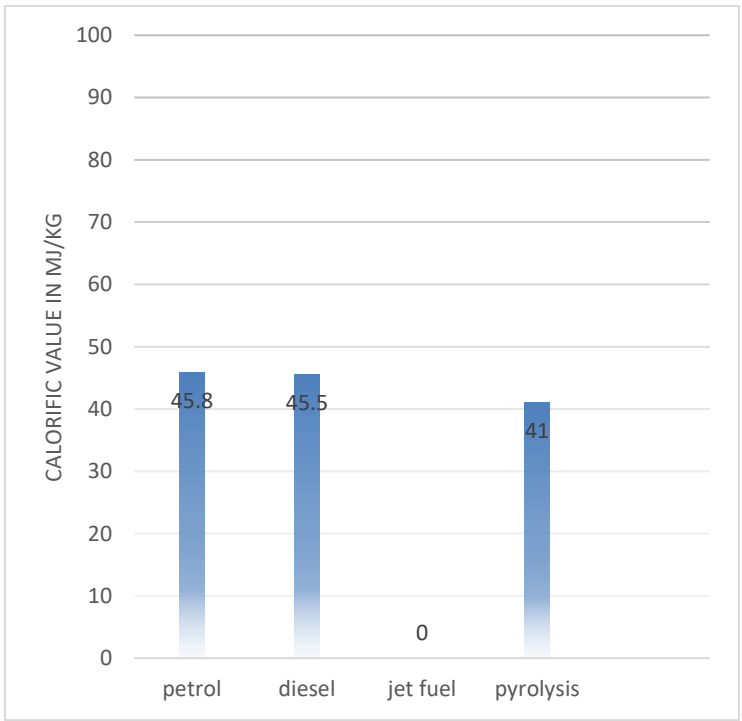
A viscometer invented by say bolt for measuring the viscosity of petroleum based liquids, typically consisting of an oil tube surrounded by a heated bath which controls the temperature of the liquid.
A standard British – type viscometer in which the viscosity is determined by the time in seconds, required for a certain quality of liquids to pass out through the orifice under given conditions; used for determining viscosity of petroleum oils.



Viscosity of Different Fuels

Calorific value:-The energy contain in fuel or food, determined by measuring the heat produced by the complete combustion of a specified quantity of it this is usually expressed in Mega joules per Kg**.**
An instrument which is used to calculate Calorific value is **Bomb Calorimeter**.

Bomb Calorimeter-A thick – walled steel container used to determine the energy contained in a substance by measuring the heat generated during its combustion.



Calorific value of Different Fuels

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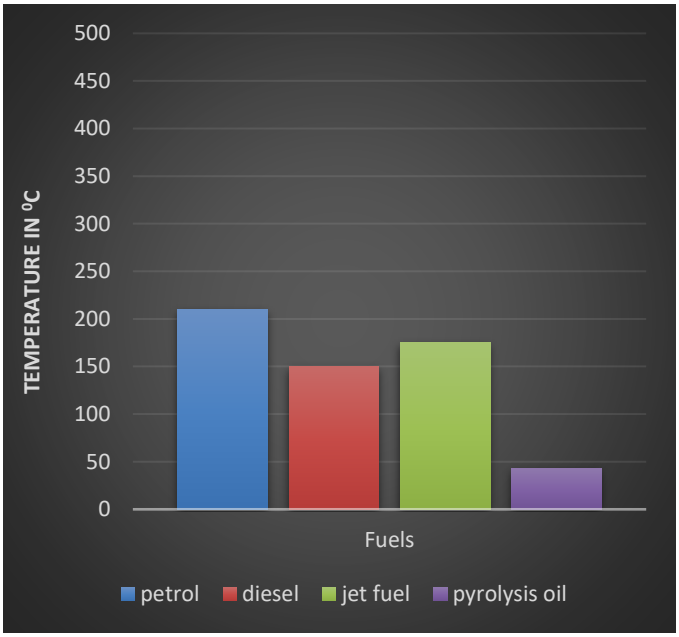
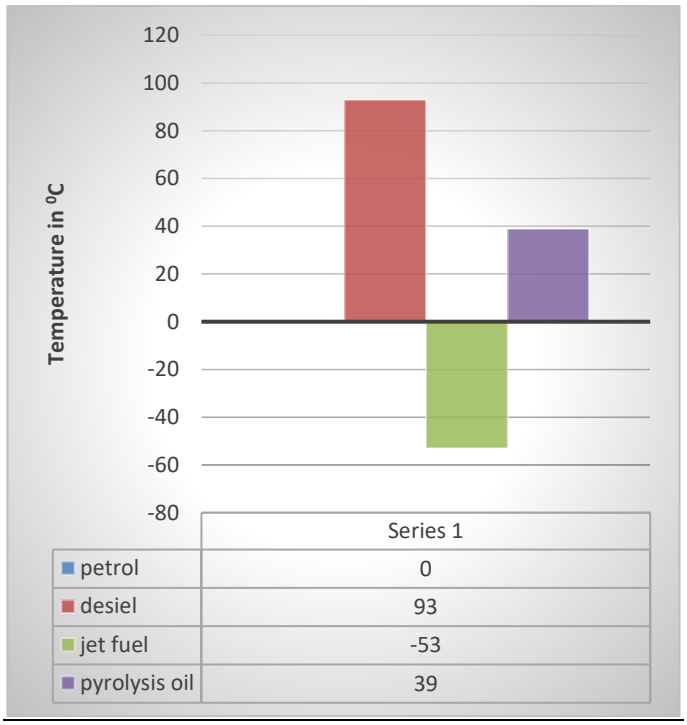


Boiling point of Different Fuels



Fire point of Different Fuels

RESULT

Pyrolysis of plastics has been studied extensively in the past **[10, 11]** , 1Kg of waste plastic will get 900ml oil can be extracted and 100gm of gas can be extracted and the remaining this is carbon block. In the pyrolysis the oil will be collected at different temperature. At the 130^{0}C 20% oil, at 210^{0}C 30% oil, at 250^0 40% oil, at 300^0 60% and at 430^0 C 90% oil will be collected.

Fuels	Boiling point (^{0}C)	Flash point(^{0} C)	Fire point(^{0} C)	Calorific valve(M J/Kg)	Viscosity cSt
Petrol	210^0	-43^0	-	45.8	0.006
Diesel	150^0 to 380^0	60^0	93^0	45.5	2.5-3.2
Jet fuel	175^0-300^0	38^0	-53^0	-	11.31
Pyrolysis oil	43^0-276^0	35^0-36^0	39^0-42^0	41-44	1.98

CONCLUSION

Cost for the fuel is increasing day by day and also the problem arising due to the improper waste disposal of plastics are increasing in our country.

This plastic to fuel machine can solve both these problem in the most efficient manner. This process offers many advantages such as:

- Problem of disposal of waste plastic is solved.
- Waste plastic is converted into high value fuels.
- Environmental pollution is controlled.
- Industrial and automobile fuel requirement shall be fulfilled to some extent at lower price.
- No pollutants are created during cracking of plastics.

The crude oil and the gas can be used for generation of electricity.

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