Process of Recovering Diesel from Waste Plastics: A Review

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Abstract

It was established that over a 100 million tons of plastics are produced annually worldwide, and they have become a common feature of the overflowing bins and landfill sites. As they are inert and non-degradable, they do not mix or make bond with other substances. As a result as we enjoy the conveniences that plastics can provide, the treatment of waste plastics becomes an imminently challenging issue. In this regard, there is an urgent need to find effective ways to recycle waste plastics. This research study is focused on recycling of waste plastics to derive automotive diesel oil for use to power engines. Waste plastics are first treated in a heater at a certain temperature, and then molten plastic is passed into a reactor where its carbon chain break down into different components depending on different temperature levels. Then finally, in the distillation chamber various gases and diesel fuel fraction are recovered.

Keywords: *Wasteplastics, landfills, recycling, diesel fuel, reactor, fraction*

1. Introduction

The major challenges posed by climate change as well as striving for security of energy supply are contemporary issues high on the political agenda of late. Various nations are putting strategic plans in motion to minimize primary energy use. The disposal of waste has to be solved under thrifty, and environmentally acceptable and hygienic conditions. Plastics are an integral part of our modern life and are used in almost all daily activities. Since plastics are synthesized from non-renewable sources and are not biodegradable, waste plastics constitute the serious environmental problems the world faces today. However, waste plastics could become a source of energy if relevant treatment technologies are used.

2. Plastic recycling overview

2.1 Plastics feedstock

Plastics are generally considered to be high heat combustion materials. They do not absorb much moisture. Water content of the plastics is far lower than the water content in the biomass.The two types of plastics are thermo-plastics and thermosets:

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Thermoplastics: These are made of long side chains. The bonds between thermo-plastics molecules are weak, and they can be softened and hardened through heating and cooling process repeatedly. Such changes do not make any changes in their chemical structure. Thermoplastics can be recycled after use. In practice, most plastic products are made from thermoplastic.
Thermosets: They are formed by a cross-linked structure during processing so they cannot be reshaped or recycled. The bonds between the molecules are very strong.

Conversion of the waste plastics into fuel depends on the plastic types and its properties. Thus all plastics are suitable for oil conversion. To get effective conversion from the waste plastics it is most important to select non-hazardous, combustible and suitable feedstock. Because some plastics contain undesirable substances such as nitrogen, halogens, sulfur and flame-retardants additives such as bromine antimony compounds. The mostly considered acceptable feed stocks are high density polyethylene (HDPE) and low density polyethylene (LDPE). Examples of HDPE entail crinkly shopping bags, freezer bags, milk bottles, as well as buckets, while LDPE examples are garbage bags, squeeze bottles, black irrigation tubes, and films bags. Also considered are polypropylene (PP) and polystyrene(PS), which are commonly used as food containers. On the contrary, polyethylene terephthalate (PET), and polyvinyl chloride (PVC) are non acceptable as feed stocks. PET plastics include soft drinks bottles, food grade packaging and trays, whereas PVC examples are pipes, window fittings, bottles and laminates. Also included in this category are foams, nylons and fiberglass.

2.2 Chemical make up

Plastics are made from petroleum based organic compounds like natural gas, oil and crude oil. These compounds consist of polymers which are made up of shorter carbon containing compound called monomer. In the petroleum refining industry, crude oil is refined into ethane, propane, and other petrochemical products such as diesel, fuel gasoline and paraffin. By applying 760^{o}C temperature ethane and propane are cracked into ethylene and propylene. After that, these ethylene and propylene gases are separated from the other hydrocarbons of petroleum products. In a polymerization reactor, these hydrocarbons are mixed with catalysts and form long polymer chain.

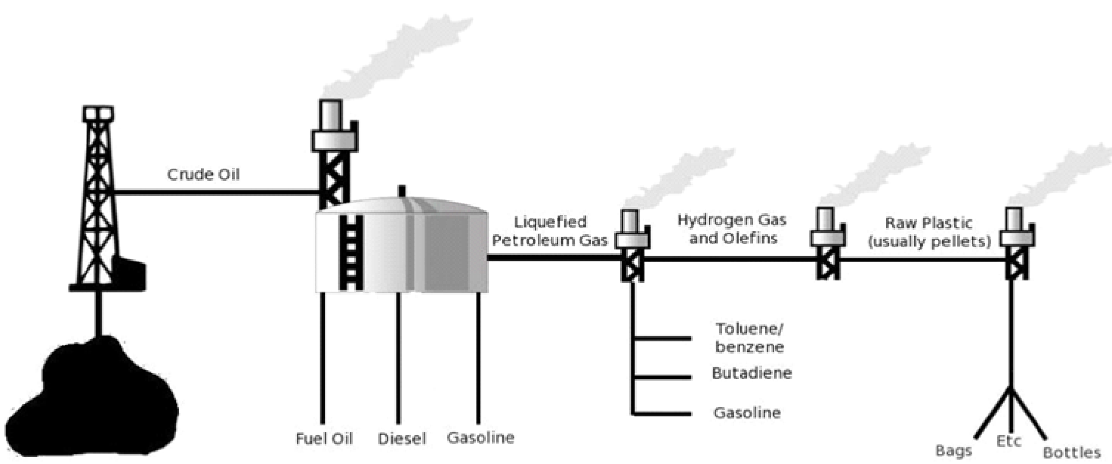

Figure 1.Schematic process of plastic from petroleum

To get oil back from waste plastics certain facts have to be revisited. Plastics are inert. So they usually do not mix or make bond with other substances. This means that plastics do not decay normally. It takes thousands of years to degrade or to break down in the environment. Some plastics do not degrade at all. As a result, plastics present many harmful problems for mankind, for environment, for animals on land or even in the oceans. The growth of plastic products and uses are increasing by day.

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2.3 Pyrolysis
Waste plastics are first treated in a heater at a certain temperature distance. Then melted plastic passed into a reactor where its carbon chain breaks down into different level sizes depending on different temperature through a process called pyrolysis. Then from the distillation chamber different gases and fuels can be collected. Pyrolysis can be taken as thermal degradation of plastics. It is a process treatment that decomposes organic materials in the absence of oxygen. It is used to produce clean, high calorific value fuel from waste plastics. The hydrocarbon content of the waste plastics would be converted into fuel or gas with a high calorific value and char which has the industrial value as a resource of energy. This technology has the operational, environmental and financial benefits. It can convert around 80-90% of waste plastics into fuel. It provides an alternative solution for the land filling problem and reduced CO_2 emission in the environment. Pyrolysis technology could be different based on whether is done with or without catalyst in the reactor, different kinds of reactor systems, temperature variation, and output product of the process.One of the most selected and significant process could be polymer cracking.

Feedstock sorting and size reduction of the waste plastics is required prior pyrolysis. Input specification of the feedstock varies according to design. Pyrolysis at atmospheric conditions is undertaken in the absence of oxygen for reason of safety, product quality and good yield. Feedstock of the waste plastics are fed to heated fluidized bed reactor. Operating temperature of the reactor is about 500 ^{o} C. The high operating temperatures and heat rate enhance bond breaking of the plastic materials into smaller hydrocarbon chains. The yield range around 85% weight of the plastic converted into hydrocarbon liquid, and 15% of into gas product. Efficient loading of the processor, is done when feedstock is passed through a shredder and granulator. The hopper is loaded with approximately 800 kg of waste plastic using a forklift. The plastic is loaded into the processor by a continuous conveyor between the hopper and reactor. The plastic is then passed into the processor chamber where it is heated at a certain temperature using its own previously made off-gas. Hydrocarbon bonds break down in the pyrolysis sector and passed to the distillation chamber. During this process inline additive such as lubricant and antioxidant are added. Finally at certain temperature level diesel is collected from the distillation chamber.

2.4 Mechanism of thermal degradation

The process is initiated and occurs on some defected sites of the plastic polymer chains. This could be catalyzed by proton addition. This would generate a reactive intermediate from a stable molecule. Thus random breakage of the C–C bond of the main chain occurs with heat to produce hydrocarbon radicals as given below.

R1–R2 = R.1 + R.2

The hydrocarbon radicals would further decompose to produce lower hydrocarbon chains such as propylene, then followed by an abstraction of H-radicals from other hydrocarbons to produce new hydrocarbon radicals. Then there occurs recombination of the free radicals. In case of cyclic compounds , they break down into linear compounds by the application of high temperature in the presence of a catalyst.

2.5 Fuel purification process and quality determination
Primary filtration on the recovered diesel filtrate is undertaken to remove insoluble particles. A charge of new diesel from the storage tank could be added to the mixture, depending on the final use of the diesel. The final process entails the removal of any traces of water at this stage. The various aspects of diesel fuel quality would be determined by assessed for application as given below:

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Caloric value*:* It is determined using an Oxygen Bomb Calorimeter. This gives the total energy released as heat when a sample under test is completely combusted with oxygen under standard conditions.

Diesel index*:* It is based on the diesel fuel density and distillation range. It gives an indication of the combustion speed of diesel fuel and compression needed for ignition. It is an inverse of the similar octane rating for gasoline.

Viscosity*:* Fuel viscosity control is a technique to control viscosity and temperature of fuel for efficient combustion in diesel engines. To maintain this value a combination of viscometer PID controller and a heater is used. Viscometer measures the actual viscosity of fuel, this value is compared with the set point in the controller and the command is sent to the heater to adjust the temperature of the fuel.

Flash point*:* This gives the lowest temperature at which vapors of a material will ignite, in the presence of an ignition source.

Fire point*:* Lowest temperature at which the vapor will keep burning after being ignited and ignited source removed. Fire point is higher than flash point, because at the flash point the vapor may be reliably expected to cease burning when the ignition source is removed.

Cloud point*:* This parameter refers to the temperature below which wax in diesel forms a cloudy appearance and indicates the tendency of the oil to plug filters at cold operating temperatures.

Pour point*:* It is the temperature at which fuel becomes semi solid and loses its flow characteristics. The specimen is cooled inside a cooling bath to allow the formation of paraffin wax crystals. At about 9^oC above the expected pour point, and for every subsequent 3^oC, the test jar is removed and tilted to check for surface movement.

Lead concentration*:* Tetra-ethyl-lead (TEL) is an organo-lead compound with formula $(CH_3CH_2)_4Pb$. Where TEL is a patented octane rating booster that allowed engine compression to be raised substantially, and in turn increases vehicle performance or fuel economy.

3. Waste plastic diesel oil

The exponential growth of plastic industry means that a corresponding large amount plastic waste is equally generated. Statistics show that the production of synthetic polymers represented by polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC) worldwide has increased more than hundred fold in the last three decades. These are widely used in many important day to day applications such as clothing, household appliances and in automotive products and aerospace. Thus addressing this menace can provide a big relief, thereby making the treatment of waste plastics an unavoidable and imminent issue. In this regard, it can be safely argued that we are in urgent need for effective ways to recycle waste plastics to useful fuels, with attention being focused on using oil derived from waste plastics in diesel engines. This initiative, would complement the processing of used oil waste which for some time has been recycled to produce diesel fuel as the waste is also produced in bulk from various operations.

4. Recommendations

This review has shown that producing diesel oil is technically feasible, economically viable, and environmentally suitable to mitigate further pollution of the environment.
There is urgent need for creating awareness for stakeholders to embrace more the research subject on this initiative and give it higher priority. Other issues to be worked would be the need to reduce viscosity of produced diesel oil from pyrolysis. As a starting point work may be carried to produce diesel for engines. Fuel properties such as distillation, aromatic content, water and sediment content and concentration of sulphur could be determined and establish their effect on engine performance.

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5. Conclusion

The paper reviewed the material on thermal pyrolysis of waste plastics as an opportunity which can yield the production of diesel fuel oil. In the process, valuable resource recovery and reduction of waste problem would have been achieved. Thermal pyrolysis of waste plastic waste has several advantages over other alternative recycling methods. In summary, it can be concluded that diesel produced from plastic pyrolysis oil could be economically used in diesel engine combustion.

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