Conversion of Plastic Waste into Fuel

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Abstract— Environmental concern and availability of petroleum fuels have caused interests in the search for alternate fuels for internal combustion engines. Conversion of waste to energy is one of the recent trends in minimizing not only the waste disposal but also could be used as an alternate fuel for internal combustion engines. Waste plastics are indispensable materials in the modern world and application in the industrial field is continually increasing. In this context, waste plastics are currently receiving renewed interest. In the present paper waste plastic pyrolysis oil, waste plastic pyrolysis oil of petrol grade and diesel grade and its blend with diesel and petrol respectively has been introduced as an alternative fuel. In this study, a review of research papers on various operating parameters have been prepared for better understanding of operating conditions and constrains for waste plastic pyrolysis oil of both grade fuel and its blends fuelled in compression and spark ignition engine.

Key words: Alternative Fuel, Diesel Engine, Petrol Engine, Engine Emission

I. Introduction

Every year humans produce nearly 280 million tons of plastic, and much of that plastic ends up in the environment, harming marine life and other ecosystems. The chemical bonds that makes plastic so durable makes it equally resistant to natural processes of degradation. Since plastics are non-biodegradable in nature, it is very difficult to eliminate the waste plastics from nature. Since 1950s 1 billion tonnes of plastic have been discarded and may persist for hundreds or even thousands of years. Expenditure incurred on disposal of plastic waste throughout the world is around US$ 2 billion every year. Even for a small country like Honk Kong spends about US$ 14 million a year on the exercise [1]. The majority of the plastic waste ends up in landfills, and becomes a carbon sink where it may take up to 1000 years to decompose and potentially leak pollutants into the soil and water. Also the plastic wastes are dumped in the oceans threatening the health and safety of marine life. The uncontrolled incineration of plastic produces polychlorinated di benzo-p-dioxins, a carcinogen. So, converting the waste plastic into crude oil will have two benefits. First of all, the hazards caused due to plastic waste can be reduced and secondly, we will be able to obtain some amount of oil from it, which can be further purified to be used as a fuel in different areas such as domestic fuel, fuel for automobiles and industries etc. Thereby, our dependency on fossil fuels will reduce to a certain extent.

II. Literature review

M.F. ali [1] 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 results 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 materials into liquefied coal products and to upgrade the petroleum residues and waste plastics

N. Miskolczi [2] 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. 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 wastes could be converted into gasoline and light oil with yields of 20 48% and 17–36% respectively depending on the used parameters.

Dipak Kumar Shaw [3] By using this process for the reduction of complex organic materials into light crude oil. It mimics the natural geological processes thought to be involved in the production of fossil fuels. Under pressure and heat, long chain polymers of hydrogen, oxygen and carbon decompose into short chain petroleum hydrocarbons with maximum length of around 18 carbons. The feedstock material is first ground into small chunks, and mixed with water if it is especially dry. It is then fed into a pressure vessel reaction chamber where it is heated at constant volume to around 250 °C. Similar to a pressure cooker (except at much higher pressure), steam naturally raises the pressure to 4 MPa (near the point of saturated water). These conditions are held for approximately 15 minutes to fully heat the mixture, after which the pressure is rapidly released to boil off most of the water. The result is a mix of crude hydrocarbons and solid minerals. The minerals are removed, and the hydrocarbons are sent to a second-stage reactor where they are heated to 500 °C, further breaking down the longer hydrocarbon chains. The hydrocarbons are then sorted by fractional distillation, in a process similar to conventional oil refining.

Amit shah [4] Plastics have become an indispensable part in today’s world, due to their lightweight, durability, energy efficiency, coupled with a faster rate of production and design flexibility, these plastics are employed in entire gamut of industrial and domestic areas hence plastics have become essential materials and their applications in the industrial field are continually increasing. At the same time, waste plastics have created a very serious environmental challenge because of their huge quantities and their disposal problems[1]. Instead of biodegradation, plastics waste goes through photo-degradation and turns into plastic dusts which can enter in the food chain and can cause complex health issues to earth habitants, through the thermal treatment on the waste plastic the fuel can be derive[2], by adopting the chemical process such as Pyrolysis can be used to safely convert waste plastics into hydrocarbon fuels that can be used for transportation[3]. The process is really simple, it is similar to how alcohol is made. If you heat plastic waste in non oxygen environment, it will melt, but will not burn. After it has melted, it will start to boil and evaporate, you just need to put those vapors through a cooling pipe and when cooled the vapors will condense to a liquid and some of the vapors with shorter hydrocarbon lengths will remain as a gas. The exit of the cooling pipe is then going through a bubbler containing water to capture the last liquid forms of fuel and leave only gas that is then burned. If the cooling of the cooling tube is sufficient, there will be no fuel in the bubbler, but if not, the water will capture all the remaining fuel that will float above the water and can be poured off the water. On the bottom of the cooling tube is a steel reservoir that collects all the liquid and it has a release valve on the bottom so that the liquid fuel can be poured out. This device works on electricity (3 phase), it has six nichrome coils as heating elements and consumes a total of 6kW (1kW each coil). The coils are turned on and off by three solid state relays, one for each phase, the relays are controlled by a digital thermostat with a temperature sensor just a bit below the lid, so that the vapor temperature can be monitored. You need to heat the plastic slowly to about 350 degrees and just wait till it does the magic. The process takes about 4 hours, but it can be shortened considerably by tweaking the design a bit. As I said, this makes a liquid fuel that can be used as multi fuel, that means it can be used on diesel engines and also on gasoline engines, but we still need to test it will work on gasoline. It works for diesel engines just fine, that has already been tested.

Nikolett Borsodi [5] The world's plastic consumption has been significantly increased in the last decades. Nowadays the disposal of the plastic wastes means a huge problem because their degradation takes a very long time in the nature. One of the plastic waste recycling processes the pyrolysis. Pyrolysis of plastic wastes is carried out in the temperature range of 400-700°C in the absence of oxygen. Among these conditions the long polymer chains are cracked into lower hydrocarbons. The energetic utilization is one of the further utilization of pyrolysis products. Plastic wastes from the packaging sector usually contain contaminants in their own material or on their surface. Chemical recycling of contaminated plastics is possible but the contaminants can appear in the products and the high heteroatom content of the products reduces their quality. The energy consumption of the pyrolysis process is quite high because of the endothermic cracking reactions. In addition the products of thermal pyrolysis have a wide carbon number distribution. Therefore there are several processes that apply catalysts in order to decrease the activation energy of the reactions. By using catalysts the reaction temperature can shifted to lower temperatures. Catalysts also change the composition of the products, eg. liquid products obtained from thermo-catalytic degradation have a lower average molecular weight therefore they are much more adequate to used as blending components of fuels. The most often applied heterogeneous catalysts are different types of zeolites and acid solids like alumina, silica alumina, aluminium pillared clays and meso structured materials However, the direct catalytic pyrolysis has a number of disadvantages. The activity of catalyst can rapidly decrease because of the contaminants (sulphur, metal and other contaminants) that are present in the plastics. The coke formation on the surface of the catalyst is another reason for the deactivation. Furthermore catalysts presents additional costs in the technology, therefore its regeneration is crucial. Nevertheless, regeneration process could be difficult because already the first step, the separation of the catalyst from the heavy oil is complicated A number of workers have investigated the thermo-catalytic pyrolysis of polymers on different zeolite catalysts. Most of these researches have applied pure plastic material or mixed plastic as raw material. Only a few investigations with real plastic wastes were presented in the literature. In some cases the effect of catalysts on the decomposition of heteroatom containing plastics was also investigated.

A. Liazid [6] The threat posed by climate change and the striving for security of energy supply is issues high on the political agenda these days. Governments are putting strategic plans in motion to decrease primary energy use, take carbon out of fuels and facilitate modal shifts (Sebastian and Thomas, 2009). Throughout the world, many steps are being taken to alternate petroleum based fuel due to tires from automotive vehicles, restaurant and plastic have become increasingly hard. Waste management is the impact of increase in oil price and the reality of petroleum depletion. Additionally, the disposals of waste once a technical problem that has to be solved under thrifty, yet environmentally acceptable and hygienic conditions and preferably performed by skilled labour. Disposal of waste vehicle tires is one of the most important problems that should be solved. It is estimated that worldwide, over one billion waste tires are generated annually (Cumali and Hüseyin, 2011). Industrial and household wastes are produced on a daily basis and are managed in many ways, depending on their type. According to their combustibility, wastes are basically categorized as either burnable or un burnable. The burnable wastes are normally treated by combustion with or without heat production, while the un burnable wastes are treated by recycling, re-use, or landfilling, depending on the material. Municipal and industrial wastes that contain high heat value, such as waste plastics oil (WPO), waste cooking oil (WCO), and waste lubricating oil (WLO) are considered efficient feed stocks for energy production in a Waste-to-Energy regimen (Ampaitepin and Tetsuo, 2010). The main objective of this paper is to analyze by means of literature review the engine performance, combustion and emission characteristics of diesel engines fuelled with biodiesel produced from waste engine, waste cooking and waste plastic oil and/or its blends with petroleum-based diesel fuel.

Vilas Watwe [7] 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 properties comparable to petroleum based fuels. Unlike rest of the world, India's demand for diesel fuels 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 fulfil Energy security needs without sacrificing 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. Utilization of biomass as alternative fuel for compression ignition engine has a great scope especially in developing and undeveloped countries. Plastics have become an indispensable part in today's world, due to their lightweight, durability, energy efficiency, coupled with a faster rate of production and design flexibility, these plastics are employed in entire gamut of industrial and domestic areas hence plastics have become essential materials and their applications in the industrial field are continually increasing. At the same time, waste plastics have created a very serious environmental challenge because of their huge quantities and their disposal problems2. Instead of biodegradation, plastics waste goes through photo-degradation and turns into plastic dusts which can enter in the food chain and can cause complex health issues to earth habitants, through the thermal treatment on the waste plastic the fuel can be derive3, by adopting the chemical process such as Pyrolysis can be used to safely convert waste plastics into hydrocarbon fuels that can be used for transportation.

Pawar Harshal R. [8] Diesel 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 properties comparable to petroleum based fuels. Unlike rest of the world, India's demand for diesel fuels 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 fulfil energy security needs without sacrificing engine's operational performance. Waste to energy is the recent trend in the selection of alternate fuels1. Fuels like alcohol, biodiesel, liquid fuel from plastics etc are some of the alternative fuels for the internal combustion engines. Utilization of biomass as alternative fuel for compression ignition engine has a great scope especially in developing and undeveloped countries. Plastics have become an indispensable part in today's world, due to their lightweight, durability, energy efficiency, coupled with a faster rate of production and design flexibility, these plastics are employed in entire gamut of industrial and domestic areas hence plastics have become essential materials and their applications in the industrial field are continually increasing. At the same time, waste plastics have created a very serious environmental challenge because of their huge quantities and their disposal problems2. Waste plastics do not biodegrade in and fills, are not easily recycled, and degrade in quality during the recycling process. Instead of biodegradation, plastics waste goes through photo-degradation and turns into plastic dusts which can enter in the food chain and can cause complex health issues to earth habitants, through the thermal treatment on the waste plastic the fuel can be derive3, by adopting the chemical process such as Pyrolysis can be used to safely convert waste plastics into hydrocarbon fuels that can be used for transportation4.

Ravi D Bumtariya [9] after performing conclude that the procedure at last we get crude oil which contains threepetroleum products Gasoline, Diesel & Petrol. Moreover we get wax as a byproduct. At the end of the process remained waste product which is a melted plastic waste has properties like naphtha. Thus we can use it in road construction instead of naphtha and also use it in various applications. In this process we get SO2 at initial stage as an exhaust gas which is also useful in pre-heating, further it should be useful to produce H2SO4.

III. The Process of Conversion of Plastic into Fuel

1) *Depolymarisation*

This process is used for the reduction of complex organic materials into light crude oil. It mimics the natural geological processes thought to be involved in the production of fossil fuels. Under pressure and heat, long chain polymers of hydrogen, oxygen and carbon decompose into short chain petroleum hydrocarbons with maximum length of around 18 carbons. The feedstock material is first ground into small chunks, and mixed with water if it is especially dry. It is then fed into a pressure vessel reaction chamber where it is heated at constant volume to around 250 °C. Similar to a pressure cooker (except at much higher pressure), steam naturally raises the pressure to 600 psi (4 MPa) (near the point of saturated water). These conditions are held for approximately 15 minutes to fully heat the mixture, after which the pressure is rapidly released to boil off most of the water. The result is a mix of crude hydrocarbons and solid minerals. The minerals are removed, and the hydrocarbons are sent to a second-stage reactor where they are heated to 500 °C, further breaking down the longer hydrocarbon chains. The hydrocarbons are then sorted by fractional distillation, in a process similar to conventional oil refining.

B. *Pyrolysis*

Pyrolysis is the chemical decomposition of organic substances by heating the word is originally coined from the Greek derived elements pyro "fire" and pyrolysis "decomposition". Pyrolysis is usually the first chemical reaction that occurs in the burning of many solid organic fuels, cloth, like wood, and paper, and also of some kinds of plastic. Anhydrous Pyrolysis process can also be used to produce liquid fuel similar to diesel from plastic waste. 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

C. *Distillation*

This process applied for petrol and diesel grade fuel production process. Waste plastic to fuel was use for further distillation process and making petrol and diesel grade fuel. Distillation column was use for distillation process. Distillation process set up different columns with different temperature profile like low boiling point fuel to high boiling point fuel. Petrol grade fuel collected from 1st fractional column and temperature range was 90°C to 130°C. Diesel grade fuel collected from 2nd fractional column and temperature range was 250°C to 285°C. In distillation process, 2nd grade fuel was diesel fuel and diesel fuel density 0.80 g/ml. This fuel hydrocarbon compound also heavier and this fuel are not igniting. Collected diesel grade fuel percentage was 29% and rest of all other fractional fuel percentage was 71% including light gas also. Fractional distillation process was also generating some light gases. Light gas cleaning procedure also same above procedure. Plastic pyrolysis fuel to different fuel by using fractional distillation column used for heat applied with different column temperature wise and fuel break down into shorter into longer chain wise and come out into different fraction column then collected into different separate container for grade wise.

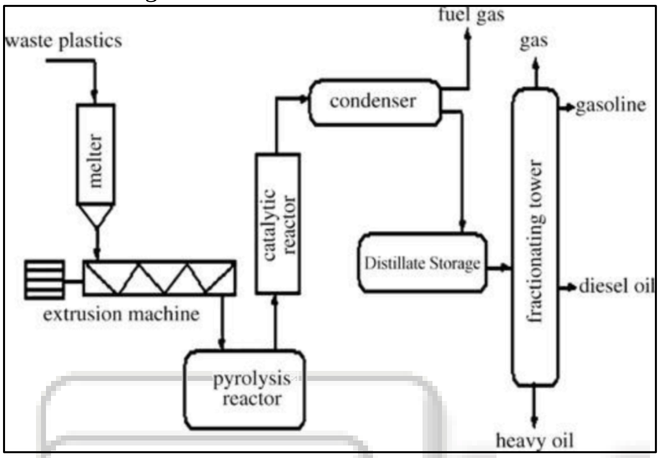

Fig. 1: Pyrolysis catalytic cracking technique of plastic wastes.

D. Benefits

1) This process has a great potential to turn the situation. By improving the process we will be able to obtain diesel and petrol fractions separately
2) Can build a mechanism sized reactor in each city and reduce landfills
3) Can be coupled with a generator to power house
4) Its decrease the pollution

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