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Conversion of Waste Plastic into Fuel by Gasification

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ABSTRACT
The disposal of plastic solid waste has become a major worldwide environmental problem. New sustainable processes have emerged, i.e., either advanced mechanical recycling of Plastic solid waste as virgin or second grade plastic feed- stock, or thermal treatments to recycle the waste. The processes help to avoid land filling, where the non-biodegradable plastics remain in the environmental causing pollution. In this project we are focusing on producing diesel via syngas; which is produced by gasification of plastic. Gasification is a process of burning feedstock at high temperature in the presence of the oxidizing agent to form syngas. The syngas produced can be used to produce wide range of products. In this project we are using syngas to produce diesel by F-T synthesis. F-T synthesis is a process in which syngas is converted into alkane in the presence of and metallic catalyst (Usually iron or cobalt). In this project we focus on optimizing the process of conversion of plastic to diesel via syngas and thereby increasing the yield of diesel.

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I. INTRODUCTION

Plastic is one of the most highly required material for humans but possesses a massive threat to the environment. Every year nearly 280 million tons of plastic is generated and much of that plastic ends up in the environment, causing environmental pollution. The chemical bonds that make plastic so durable makes it equally resistant to the natural process of degradation. Since plastics are non-biodegradable in nature, it is very difficult to eliminate waste plastics from nature. As a brief introduction to plastics, it can be said that Plastic is the term which refers to a wide range of synthetic or semi-synthetic organic amorphous solid materials which are typically of high molecular mass.it is a relatively cheap, durable and versatile material, however due to this, the huge amount of plastic waste that resulted from the dramatic increase in plastic production gives rise to serious environmental concerns, as plastic does not degrade. If this problem is not addressed properly, it will to accumulation of humorous amounts of waste plastics as waste plastics are one of the most promising resources for fuel production. Plastic waste recycling can provide an opportunity to collect and dispose of plastic waste in the most environment friendly way and it can be converted into resource. The present rate of economic growth is highly on fossil fuel crude oil, natural gas, coal. This has been a driving technology since years but with the increased demand and high price for energy sources now we need to look for a sustainable solution which is important for sustainable development. To overcome this issue and to find a sustainable solution, driving efforts to convert organic compounds into useful hydrocarbon fuels are undertaken. There are strong benefits to deriving fuels from the waste plastic material. Thermal processes such as Pyrolysis and gasification can be used to convert plastics into hydrocarbon fuels such as gasoline, diesel, aviation/jet fuel which have unlimited applications in heavy transportation, airline industries and electricity generation. Using waste plastic as a resource for the production of these conventional fuels can greatly reduce the plastic waste accumulated in the environment and support the high demands of conventional fuels at the same time.

Keywords – Waste plastics . Pyrolysis . Fuels . Gasification

II. TYPES OF PLASTIC

Plastic is as versatile as it is recyclable. By recycling the plastics, you use every day, you can reduce your impact on the environment and help businesses cut costs [1]. PET is commonly found in beverage bottles, perishable food containers and mouthwash, clear PET plastics are generally considered safe, but can absorb odors and flavors from foods and liquids stored in them. HDPE is a commonly recycled plastic deemed safe. HDPE products tend to have a very low risk of leaching into foods or liquids. You can find this plastic in milk jugs, yogurt tubs cleaning product containers, bodywash bottles and similar products. PVC is found in food wrap, plumbing pipes, tiles, windows and medical equipment, PVC is seldom recycled. PVC plastics contain harmful chemicals linked to a variety of ailments, including bone and liver diseases and developmental issues in children and infants. More recycling programs are beginning to accept LDPE plastics. A very clean and safe plastic, LDPE is found in household items like plastic wrap, grocery bags, frozen food containers and squeezable bottles. PP is quite sturdy and found in Tupperware, syrup bottles, medicine bottles and yogurt containers. PP is recycled into heavy-duty items like pallets, ice scrapers, rakes and battery cables[2]. Many recycling programs accept PP. PS or Styrofoam is found in beverage cups, insulation, packing materials, egg cartons and disposable dinnerware. Styrofoam is notorious for leaching and poor recyclability, though some programs may accept it.

Table No. 2.1

Type of plastic	Density (g/cc)
Polystyrene	0.961
Polypropylene	0.905
HDPE	0.965
LDPE	0.910
PVC	1.38
PET	1.39

III. PROCESS

The mixed plastic wastes converted to F–T liquid predominantly displace the production of diesel from fossil sources. The mixed plastic wastes are transported to where they are dried and gasified using oxygen to produce crude syngas, which is further cooled and cleaned up. Prior to the F–T process, the syngas is processed in a water-gas shift reactor to increase the hydrogen level to that required for the production of F–T liquids and waxes. The F–T liquids produced fall within the diesel hydrocarbon range, and the F–T waxes can undergo further refining to produce more diesel.

3.1 Stage 1

Waste plastics as a reactant for obtaining the valuable products are invariably contaminated with materials such as soil, iron and wood etc. and also consist of various types of plastics. This material cannot be directly used in the gasification process. Therefore, in the next step separation treatments must be applied to obtain waste plastic with a homogeneous composition. If it contains a lot of various contaminative materials in waste plastics, it leads to poor economics by increasing the recycling procedure cost. The waste material must be separated into individual components, such as thermoplastic, PVC, PET, thermosetting, iron, aluminum and paper, etc. [4] In some cases, the when the metals are present in the waste then magnetic separator is used to remove the metal from waste plastic.

The plastic is then crushed into small pieces in a crusher in order to increase the area of contact for the gasification process and it also becomes easy to handle. After this the plastic is sent to the drier where all the moisture content of the plastic is removed and then it is preheated before sending it to the gasification reactor. By preheating the plastic feedstock, the melting time in the melting reactor can be shorted thus improving production rates. Moreover, the film type reactant is very bulky and voluminous, which makes it difficult to ensure continuous feeding, is easily dosed at the melting system after melting in the feeding system. In the unheated case, a hard reactant of several millimeter size is adequately controlled by a continuous feeding system. Thus, the feeding system will be determined by the profile of waste plastics that are exited from industry, agriculture and household, etc. Other important point is that if there is trouble in a continuous automatic feeding system, it can be quickly transferred to a manual system. Moreover, as the system is scaled up to a big plant, this is a very important parameter for heating the feeding system [5].

The preheated feed is then sent into the gasification reactor. Gasification efficiently utilizes the chemical energy and recoverable raw materials inherent in unsorted domestic waste, industrial and special waste (e.g. medical waste), and is capable of transforming almost all of the total waste input into technically usable raw materials and energy. The process essentially oxidizes the hydrocarbon feed-stock in a controlled fashion to generate the endothermic depolymerization heat. The primary product is a gaseous mixture of carbon monoxide and hydrogen, with minor percentages of gaseous hydrocarbons also formed. This gas mixture is known as syngas and can be used as a substitute for natural gas or in the chemical industry as feedstock for the production of numerous chemicals. For gasification reactor a fluidized bed is used and the oxidizing agent we are using is 90% oxygen instead of air. Air consists of 79% nitrogen which dilutes the reactive components of the feed and causes the reduction in the calorific value of resulting syngas due to the dilution. An ideal gasification process for PSW should produce a high calorific value gas, completely combusted char, produce an easily recoverable ash. Gasification produces three different phases: a solid phase (char), a liquid phase (tars) and a gas phase. First products yielded are usually in the range of C20 to C50. These products are cracked in the gas phase to obtain lighter hydrocarbons, as ethene and propene, which are unstable at high temperatures and react to form aromatic compounds as benzene or toluene. In thermo-chemical treatment of polyolefins (mainly PE and PP), products obtained mainly depend on cracking reactions in the gas phase. Long residence time of volatiles in reactors and high temperatures decreases tar production but increases char formation. The reactor is heated above 800 C and steam is introduced into the reactor which reacts which the carbon char formed by heating it at such high temperatures to form a synthetic gas i.e. syngas which comprises of carbon monoxide, carbon dioxide and hydrogen.

The syngas produced in the gasification reactor is then cooled in a water-cooled condenser. Thereafter it is passed through a bag filter where the solid particles present in the gas are removed. After filtration the syngas is sent into a separator where it is separated from other waste gases. The clean syngas is then compressed and then stored in the gas storage tank for further use.

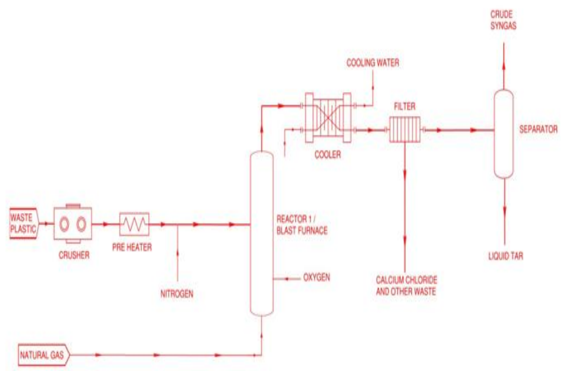

Figure 3.1.1

3.2 Stage 2

The syngas produced in the stage 1 can be used to produce gasoline, diesel and aromatics. It can also be used to produce heat in the plant. In this process we are using syngas to produce diesel using Fischer Tropsch method. Fischer - Tropsch (F-T) synthesis converts hydrogen and carbon monoxide into a wide boiling range of hydrocarbons. The hydrogen and carbon monoxide (synthesis gas) can be produced from a variety of carbon-bearing feed stocks. The resulting F-T hydrocarbon stream can be further processed to specific boiling - point fractions and upgraded to high - value products.

Before F-T synthesis steam reforming is carried out at 200 C. It is also called water shift as it increases the amount of hydrogen in the syngas which favors higher yields of diesel. After water shift the H2:CO in the syngas becomes 2:1. The shifted syngas is then sent to fixed bed reactor where F-T synthesis takes place. Cobalt is used as a catalyst instead of iron since it reduces the temperature required for heating from 350 (when iron is used) to 220-240 C. The reaction in the F-T reactor is exothermic in nature. The operating pressure of the reactor is 10-30 bar. The liquid products are recovered after gas/liquid and liquid/ solid separations and sent to the upgrading section. The liquid/solid separation takes place outside the reactor in an external slurry loop for a safer operation and easier maintenance. The gas obtained from the GL separation is recycled back to reformer. The liquid obtained after separation is cooled in a heat exchanger. The wax and hydrocarbon condensate produced by the low temperature F-T process is predominantly linear paraffins with small fraction of olefins and oxygenate. The hydrogenation of the olefins and oxygenates and the hydrocracking of the wax to naphtha and diesel can be done at relatively mild conditions. In the design of the hydro-cracker, a balance must be found between the per-pass conversion, diesel selectivity and diesel properties. The higher the per-pass conversion, the smaller the cracker will be due to the lower recycle of material back to the cracker. This will, however, be at the expense of the diesel selectivity, since over-cracking of the liquid to gases will occur [6]. Another compliance factor is that the per-pass conversion also influences the diesel quality. The higher the pre-pass conversion, the better the cold flow properties but the lower the cetane value will be, due to the increased degree of isomerization.

The final product after hydrocracking obtained consists of diesel and naphtha. The fully converted product is separated into approximately 70% of an ultra-clean FT diesel (no Sulphur, no aromatics) having a high cetane number (> 60) and excellent cold flow properties, and 30% of a pure paraffinic naphtha — an ideal feedstock for petrochemical production.

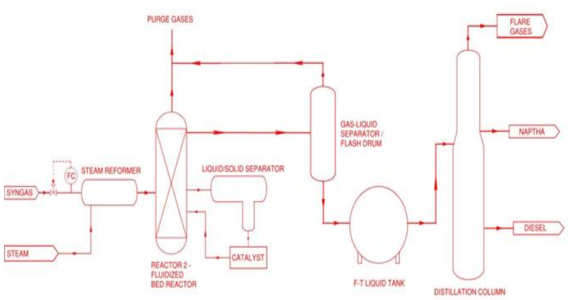

Figure 3.2.1

IV. MATERIAL BALANCE

4.1 Drying

Table 4.1.1

Input	
Components	Quantity (kg/hr)
Mixed Waste Plastic	1000
Output	
Components	Quantity (kg/hr)
Dried Waste Plastic	950
Water	50

4.2 Gasification Reactor

Table 4.2.1

Input	
Components	Quantity (kg/hr)
Dried Waste Plastic	950
Oxygen 90% pure	950
Output	
Components	Quantity (kg/hr)
Crude Syngas	1881
Ash	19

4.3 Cooling and Separation

Input	
Components	Quantity (kg/hr)
Crude Syngas	1881
Output	
Components	Quantity (kg/hr)
99% Pure Syngas	1749
Tar	132

4.4 Steam Reforming

Input	
Components	Quantity (kg/hr)
Pure Syngas	1749
Steam	583
Output	
Components	Quantity (kg/hr)
Shifted Syngas (2:1)	2332

4.5 Fischer Tropsh Reactor

Input	
Components	Quantity (kg/hr)
Shifted Syngas	2332
Output	
Components	Quantity (kg/hr)
Purge Gas	1166
FT Liquids	583
Water	583

4.6 Distillation

Input	
Components	Quantity (kg/hr)
FT Liquids	583
Output	
Components	Quantity (kg/hr)
Diesel	437.25
Naphtha	145.75

V. ADVANTAGES

The management of plastic waste is a big concern for all countries in the world. Every year 280 million tons of waste plastic is generated which directly or indirectly ends up in landfills or oceans. This project requires huge amounts of plastics waste that indirectly leads in decrease of plastics waste. It reduces the amount of plastic waste going in landfills and oceans significantly thus proving plastics resourceful. The plastic waste is a mixture of various types of plastics such as PP, PET, PVC etc. During recycling, a very less percent of plastic is recycled making the process in-efficient. This project uses all kinds of plastic as raw material and converts them to useful products thus making the recycling process more efficient. Additionally, the by-products which are obtained while recycling are also converted into useful products. This project converts waste plastic into fossil fuels in a very efficient manner. We get fuels such as Diesel, Naphtha and Natural Gas which have large scope for applications. The fuels that are obtained by the process tend to have lower carbon emission compared to that of the traditionally obtained fossil fuels thus reducing the carbon emission in the atmosphere. Every year 8 million tons of plastic is released in the oceans and 27 million tons of plastic is dumped in landfills which results in environmental pollution affecting on the life of living organisms directly or indirectly. This project uses waste as a raw material irrespective of its type and location which enables us to reduce the amounts of plastic which pollutes the environment.

VI. DISADVANTAGES

The project is based on the conversion of plastics and requires huge amount raw material to meet the breakeven production of diesel. The amount required to meet breakeven production per year is around 16000 tons/year which approximately is 44 tons/day. Obtaining this much amount of plastic per day might be difficult. The waste plastic used as raw material is a mixture of various kinds of plastics. The composition of each kind of plastic is unknown. Hence there is a requirement of segregation of the waste plastics which might add into the project cost. Another way is to buy segregated waste plastic from the retailers which results in increase in the cost of raw material. This project aims to find an alternative source of fossil fuel by the use of waste plastic. However, today's world is proceeding towards electrification as a sustainable way of living. This causes investors to invest into sustainable technologies more rather than the ones which focuses to use conventional fuels. The project deals with several reactions such as gasification, pyrolysis etc. These reactions need highly specific and accurate instruments which have high costs which adds up in high initial investment.

VII. FUTURE PROSPECT

The concept of plastics-to-fuel is particularly exciting as an option to recover materials that may be buried, or in some regions, illegally dumped or burned in open pits due to inadequate waste management infrastructure. Many developing economies currently use diesel with relatively high Sulphur content. Plastics-derived fuels can deliver a cleaner-burning fuel, due to the low Sulphur content of plastics Many companies like chevron and BP are using different techniques to produce and generate their own energy using plastic waste. The global economy will enhance after covid 19 pandemic, which is why energy requirements are expected to increase exponentially in the coming years. In the next 5 years the fuel consumption of India is expected to grow by 4.7%. As the fossil fuels are depleting at alarming rates and hence the production by fossil fuel will decrease but as the demand is increasing the price will increase.

VIII. CONCLUSION

This work focused on the conversion of plastic into diesel using Fischer Trosph synthesis. In this process the plastic is dried and the heated at very high temperature in the presence of oxygen to produce syngas which undergoes F-T synthesis in the presence of cobalt catalyst to give naphtha and diesel as end product.

Diesel is a clean burning fuel and it is 33% more efficient than gas. The diesel produced from fossil fuel contain high amount of Sulphur whereas the quantity of Sulphur present in the diesel produced by this process is significantly lower. The raw material used in the process is the waste plastic. Natural decomposition of plastic can last up to 400-1000 years. Plastic is present in seas and other water bodies in large quantities. It is harmful to both animals and humans. Diesel is produced from crude oil which is produced from fossils which takes millions of years to form and it is a limited resource and hence the production of fuels will reduce but the demand is set to only rise hence the market for diesel will remain strong and many countries are providing various subsidies to convert waste into fuel or energy and the number of people interested to invest are increasing.

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