Journal of Materials Science and Engineering B 1 (2011) 86-89
Formerly part of Journal of Materials Science and Engineering, ISSN 1934-8959

Conversion of Plastic Wastes into Fuels

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Received: October 23, 2010 / Accepted: November 10, 2010 / Published: June 10, 2011.

Abstract: Plastics have woven their way into our daily lives and now pose a tremendous threat to the environment. Over a 100 million tones of plastics are produced annually worldwide, and the used products have become a common feature at overflowing bins and landfills. Though work has been done to make futuristic biodegradable plastics, there have not been many conclusive steps towards cleaning up the existing problem. Here, the process of converting waste plastic into value added fuels is explained as a viable solution for recycling of plastics. Thus two universal problems such as problems of waste plastic and problems of fuel shortage are being tackled simultaneously. The waste plastics are subjected to depolymerisation, pyrolysis, catalytic cracking and fractional distillation to obtain different value added fuels such as petrol, kerosene, and diesel, lube oil, furnace oil traction and coke. The catalyst used here is a mixture of zeolite, clay, alumina and silicates in different proportions. Converting waste plastics into fuel hold great promise for both the environmental and economic scenarios. Thus, the process of converting plastics to fuel has now turned the problems into an opportunity to make wealth from waste.

Key words: Waste plastics, pyrolysis, catalytic cracking, depolymerisation, fractional distillation.

1. Introduction

Plastics play an important role in day-today life, as in certain application they have an edge over conventional materials. Indeed, their light weight, durability, energy efficiency, coupled with a faster rate of production and more design flexibility, have allowed breakthroughs in fields ranging from non-conventional energy, to horticulture and irrigation, water-purification systems and even space flight.

However one has to accept that virtues and vices co-exist. Plastics are relatively cheaper and being easily available has brought about use and throwaway culture. Plastics waste management has become a problem world over because of their non-degradable property. A majority of landfills, allotted for plastic waste disposal, are approaching their full capacity. Thus recycling is becoming increasingly necessary.

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2. Plastics in Environment

Three million tones of waste plastics are produced every year in the U.K. alone, only 7% of which are recycled. In the current recycling process usually the plastics end up at city landfills or incinerator. As with any technological trend, the engineering profession plays an important role in the disposal of plastic waste. Discarded plastic products and packaging materials make up a growing portion of municipal solid waste. 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 Global Environment Protectional Agency [GEPA] estimates that by the year 2004 the amount of plastic thrown away will be 65% greater than that in the 1990's [1]. The recycling of the plastic is only about one percent of waste plastic in the stream of waste in developing countries as compared to a rate of recycling of aluminum which is about 40% and 20% for paper, where as recycling rate in India is very high up to 20% of waste plastic.

In a short span of five years plastics have captured 40% of total 6.79 billion USD packaging market in India. This situation may grow further in the coming years with more and more US and European companies entering the market. It would be very interesting to note the type of litter we generate and the approximate time it takes to degenerate. Table 1 shows the time taken to degenerate for different waste materials [1].

India has been used as a dumping ground for plastic waste, mostly from industrialized countries like Canada, Denmark, Germany, UK, Netherlands, Japan, France and the United States.

Each year more than 100 million tones of plastic are produced worldwide. Though plastics have opened the way for a plethora of new inventions and devices it has also ended up clogging the drains and becoming a health hazard. The plastic waste accounts to about 10 thousand tons per day in India. At these alarming levels of waste generation, India needs to set up facilities for recycling and disposing the waste.

3. Process Technology

3.1 Pyrolysis-Catalytic Cracking Upgrade

The pyrolysis by direct heating was adopted to produce the paraffin and crude oil from the plastic wastes in the 1990s. The small-scaled process is featured by facilitation, convenience and low equipment investment However, the temperature caused by pyrolysis is higher and all the reactive time is longer than the other methods. The octane number of gasoline gained is relatively low and the pour point of diesel oil is high. More paraffin is produced in the process of pyrolysis. Although this process is simple and convenient, the converting rate and yield is still lower.

Table 1 Degradability of different waste materials.

Type of litter	Time for degradation
Organic wastes, paper, etc	1-3 weeks
Cotton cloth	8-20 weeks
Wood	10-15 years
Tin, aluminium, etc	100-500 years
Plastics	*A million years??*

The total yield of fuel oil is 50-65% [2, 3]. The other problem for this process is the pyrolysis equipment's corrosion incurred by PVC in mixed plastic wastes [4]. Therefore, it is strongly recommended to establish a reasonable sorting system and apply an efficient technique to eliminate the toxic emissions and highly corrosive hydrochloric acid that is formed.

Since the total yield of fuel oil with pyrolysis is still lower and the quality of oil is not satisfied as gasoline and diesel oil, the upgrade by catalytic cracking for the crude products gained with pyrolysis can be used. Having improved the quality of finished oil, this process has been widely used in many factories [5-7].The system consists of the knapper, extrusion machine, pyrolysis reactor, catalytic cracking reactor, fractionating tower, heating and temperature controller, separator of oil and water, and oilcan.

An improved apparatus apart from the pyrolysis reactor, consists of a cylindrical rectangular vessel heated by electrical heating coils or any other form of energy, the said vessel is made of stainless or mild steel, surrounded by heat reflector and insulator to avoid heat loss. It is provided at its side an outlet vent which connects with the condensing section which is made up of stainless or mild steel provided with an outer jacket for circulating cold water or any coolant, the condenser is connected to the receiving section and to a gasometer. The receiving unit is maintained at -40 °C to higher temperature to collect the distillate.

The catalyst for the process is prepared by using the ingredients in the proportion indicated in Table 2.

Faujasite zeolite -- 05 - 35 wt%;

Pseudoboehmite alumina-- 10 - 40 wt%;

Polyammonium silicate -- 01 - 10 wt%;

Kaolin clay -- 15 - 60 wt%.

Milling the said ingredients and making slurry using demineralized water, spray drying the slurry to micro-spheres, and calcining at 500 °C for 1 h [8]. The finished oil consists of gasoline (60%) and diesel oil (40%).

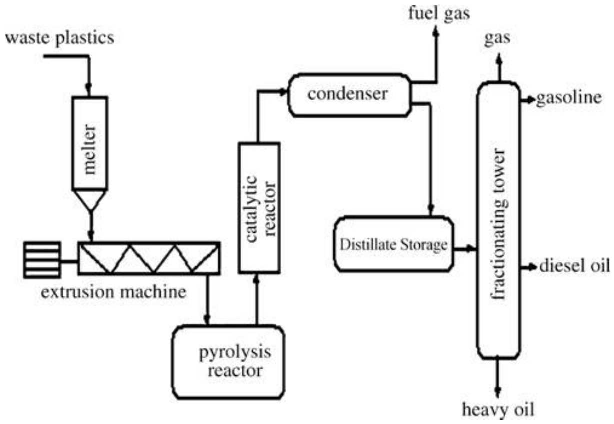

Fig. 1 Pyrolysis catalytic cracking technique of plastic wastes.

Table 2 Comparison of petrol from waste plastics with regular petrol.

S.No	Specifications	Regular petrol	Petrol from plastic wastes
1.	Specific gravity at 28 °C	0.7423	0.7254
2.	Specific gravity at 15 °C	0.7528	0.7365
3.	Gross calorific value	11210	11262
4.	Net calorific value	10460	10498
5.	Api gravity	50.46	60.65
6.	Aniline point in °C	48	28
7.	Aniline point in ^{0} f	118.4	82.4
8.	Flash point	23	22
9.	Pour point	< -20 °C	< -20 °C
10	Cloud point	< -20 °C	< -20 °C
11.	Reactivity with ss	nil	nil
12.	Reactivity with ms	nil	nil
13.	Reactivity with cl	nil	nil
14.	Reactivity with al	nil	nil
15.	Reactivity with cu	nil	nil
16.	Octane rating	83	95
17.	Mileage	44.4	44.0
18.	Time for 0-60 kph	22.5 sec	18.1 sec
19.	Co % at 400 rmp/hc	2.8	3.5
20.	Comments on engine noise	more	less

3.2 Properties and Purity of Fuels

The properties of liquid distillate match with properties (Ex: specific gravity and pour points) of high quality imported crude. The fuels obtained in the waste plastic process are virtually free from contaminants such as lead, sulphur and nitrogen. In the process (i.e.) the conversion of waste plastic into fuels, the properties mentioned above of petrol & Diesel fractions obtained are of superior quality with respect to regular commercial petrol and diesel purchased locally and has been proved by the performance test. During the process, hazards related to health and safety is reduced to 90% as compared to regular refinery process.

3.3 Quality of Fuels

The quality of gasoline and diesel fractions obtained in the process is not only at par with regular fuels in tests like sp – gravity is 0.7365 /15 °C CCR (conradson carbon Residue) Ash, calorific value etc but it is also better in terms of quality in test like flash point, API gravity. Table 2 gives the comparison of plastic derived petrol with regular petrol [9].

3.4 Additives

Regular fuels obtained from crude oil like gasoline and diesel are subjected to many reactions and various additives are added to improve combustion and meet BIS characteristics before it is introduced to market. However the fuel (Gasoline, Diesel) fractions obtained in the process can be utilized without much processing.

3.5 Yield

The average percentage output yield of the products in the first phase of reaction depending on the composition of the waste plastic is as follows:

Liquid Distillate> 110% - 115 % ;
Coke> 09 % - 10% ;
Gas > 21 % - 22% ;
LPG > 14% - 16% ;
Hydrogen > 01% - 02 %.

The percentage of liquid distillate is mentioned in terms of weight by volume whereas percentage of coke & gas are mentioned in terms of weight by weight [1].

During the second phase of reaction (i.e.) fractional distillation, the average percentage yields of various fuel fractions depending on the composition of the waste plastic are follows:

Gasoline: 60%;
Diesel: 30%;

Table 3 Process brief for 1 KG input and the yield of output.

Input	Qty Kg	Rate per Kg	Amount (Rs)	Output	Qty (*l*)	Rate per liter	Amount (Rs)
Plastic	1.00	12.00	12.00	Petrol	0.600	37.50	22.50
Labour*			5.00	Diesel	0.300	25.50	7.65
Service charge			2.50	Lube oil	0.100	15.00	1.50
Total	1.00		19.50		1.00		31.65

* Lubricating oil: 8–10%.

3.6 Feasibility

The production of the fuels from the waste plastic of various sorts has been carried out a number of times to arrive at the unit cost of production. The break - up of the cost for per kg input of the plastic and the related output for the same is depicted in the Table 3.

4. Conclusions

Plastics present a major threat to today's society and environment. Over 14 million tons of plastics are dumped into the oceans annually, killing about 1,000,000 species of oceanic life. Though mankind has awoken to this threat and responded with developments in creating degradable bioplastics, there is still no conclusive effort done to repair the damage already caused. In this regard, the catalytic pyrolysis studied here presents an efficient, clean and very effective means of removing the debris that we have left behind over the last several decades.

By converting plastics to fuel, we solve two issues, one of the large plastic seas, and the other of the fuel shortage. This dual benefit, though will exist only as long as the waste plastics last, but will surely provide a strong platform for us to build on a sustainable, clean and green future. By taking into account the financial benefits of such a project, it would be a great boon to our economy.

Acknowledgments

The authors gratefully acknowledge the extensive support given by Mrs. Alka Zadgaonkar and Mr. Umesh Zadgaonkar and for their guidance and kindness.

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