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Conversion of Waste Plastics to Fuel - Liquid Phase Contacting Recycle Technique

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Abstract—Solid waste management (SWM) is synonymous with handling and disposing of the waste in suitable ways. Solid waste is a mixture of organic waste, paper, plastics etc. Many recycling procedures are prevalent for processing paper and organic waste into useful material in eco friendly ways. The challenge associated with SWM is waste plastic accumulation; plastics are non-biodegradable polymers mostly containing carbon, hydrogen and few other elements such as chlorine, nitrogen. Disposal methods followed currently for handling waste plastics majority pose threat to environment either by polluting air as a result of incineration or soil by dumping. The novelty of current research is to convert waste plastics into fuel oil which can be used directly or indirectly in energy sector using simple reactor and economically feasible catalyst. Waste plastics like LDPE and PP were processed in a batch reactor at a temperature range of 420-4500C with clay catalyst in a ratio of 4:1 and the yield was around 60-72 percentage (weight basis). Physical and chemical analysis of product oil obtained confirms the presence of paraffin's and olefins.

Keywords:- Waste Plastic; Clay Catalys; Plastic to Fuel; LDPE; PP; Plastic Degradation; Plastic to Fuel.

I. INTRODUCTION

"Solid waste" refers to the refuse, the solid and semi solid waste matter of a community except the night soil. Solid waste contains rganic as well as inorganic matter. Solid waste management includes the entire process of dealing with solid waste, starting with the collection from the primary source to ultimately disposing it in a responsible way, so that it may not be a nuisance or create any harmful effect on nearby community and environment. The solid waste management approach in India is inefficient, using old and obsolete system, technology for storage, collection, processing, treatment and disposal. India produces around 42 Million tons of solid waste annually [1]. In spite of several organized process available, there is no formal practice for organized system of segregation of biodegradable and non biodegradable solid waste. The recovery and recycling of waste is only done by scavengers and scrap dealers which is highly hazardous to those who are involved in this job [2, 3].

It is worth to mention that usage of plastic packaging's and products has increased multi-fold in the last one decade due to its low price and convenience, however, majority public is not aware of impact of littering or dumping on the human and environment. In India, approximately 12 Million tones plastic products are consumed every year (2012), which is expected to rise further. It is also known that about 50-60% of its consumption is converted into waste. Main usage of plastics is in the form of carry bags, packaging films, wrapping materials, fluid containers, clothing, toys, household applications, industrial products, building materials etc.

It is true that conventional (petro-based) plastic waste is non biodegradable and when it is dumped on land-fill site, remains on landscape for several years polluting environment due to its high half life period. It is also well established that all types of plastics waste can't be recycled. It accumulates into open drains, low-lying areas, river banks, coastal areas, beaches etc. Further, recycling of a virgin plastic product can be done 3-4 times only that too mixing with virgin plastics granules, therefore, after every recycling its tensile strength and quality plastic product deteriorate. Besides, recycled plastic are more harmful to the health and environment than the virgin products due to mixing of color, additives, stabilizers, flame retardants etc. It would be worth to mention that no authentic data is available on generation of plastic waste in the country [4]. Recycling techniques for waste plastics are shown in the figure 1.

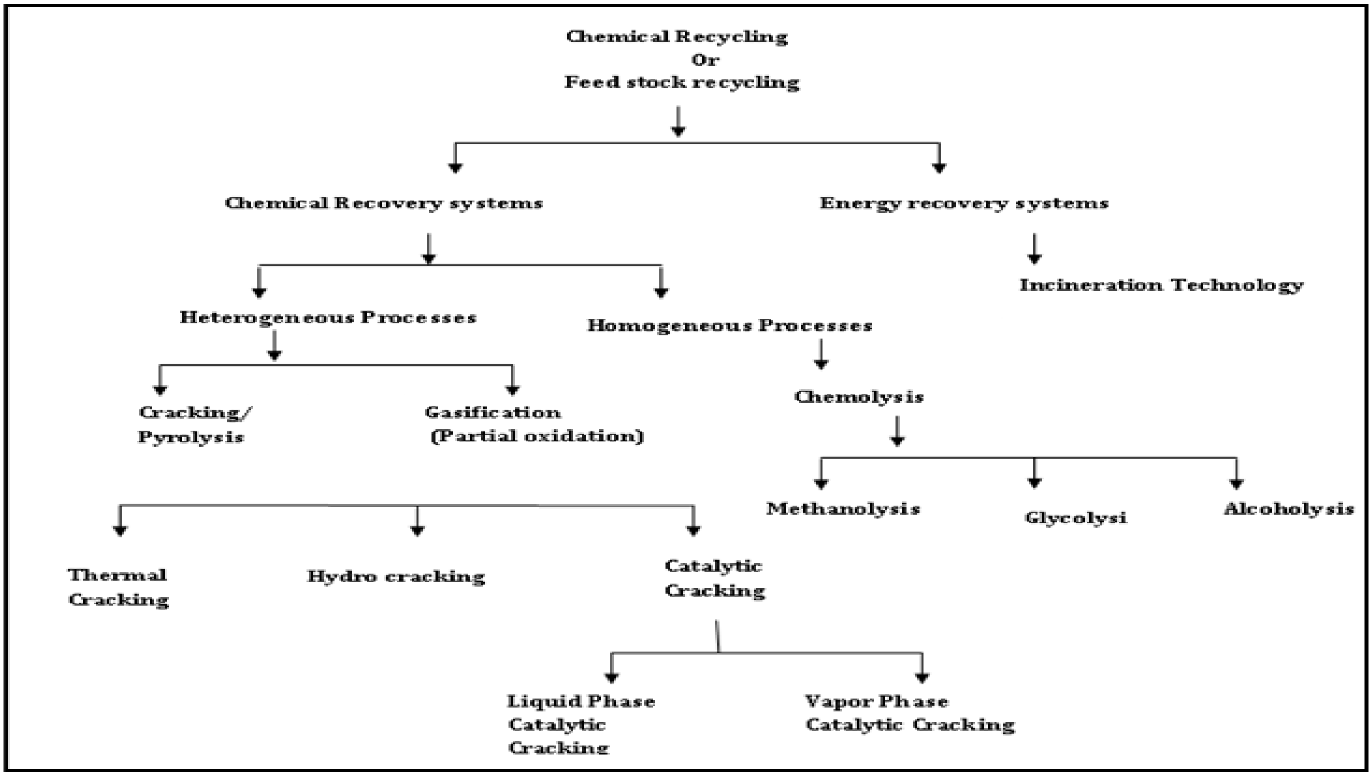

Fig.1. Chemical Recycle

Among all the techniques paralysis is gaining importance in producing value added product from waste plastics in very simple operating procedure comparative to others. Many systems followed to produce fuel from waste plastic paralysis [5, 6] and succeeded. The yield was 40-50%, and later paralysis tried in presence of variety of catalyst like zeolite (ZSM-5, HY, Hb), Silica-alumina, FCC catalyst (USY, Ecal-F1, MCM-41, ASA) Kaolin clay, Activated carbon/or Calcium oxide, E-cat, Faujasite zeolite and Pseudoboehmite alumina [7, 8, 9, 10, 11, 12, 13] which given a wide scope for higher yield as well as control in product fractions. The catalysts used in paralysis are majorly based on alumina-silicate compounds. Clay materials are also belongs to the same category. Clays regarded as green catalytic materials [14] as they are naturally available and can be used with minimum processing. They are non-corrosive solid materials, have flexibility for easy fabrication into desired shape and size, could easily be separated from product stream and are disposable relatively easily after the use with no threat to environment. Among the clays, the most used catalysts in chemical transformations are the Montmorillonites. Several options for the surface modification of montmorillonite practiced by clay chemists are available like pillareding using ultrasonication [15], acid activation [16].

Waste plastic pyrolysis generally done using two distinguish method based on contact of plastic and catalyst viz 'liquid phase contact' and 'vapor phase contact'. In 'liquid phase contact', the catalyst is contacted with melted plastics and acts mainly on the partially degraded oligomers from the polymer chains; in 'vapor phase contact', the polymer is thermally degraded into hydrocarbon vapors which are then contacted with the catalyst. The current work is production of liquid hydrocarbon fuel by the application of liquid phase contact catalytic cracking [17].

II. MATERIALS AND METHOD

A. Materials

The raw material involved for the experiment is polypropylene (PP) (shredded and non-shredded), Low density polyethylene (LDPE) (shredded and non-shredded) and Linear low density polyethylene (LLDPE) (shredded) are used. Shredded plastics are in the size range of 3mm to 5mm brought from Local Industrial area. Non shredded plastics like bottles and bags are collected from the dump yard and segregated, washed with water to remove dirt, dried and cut into small non-uniform (3mm-8mm) size.

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B. Catalyst

Clay catalyst used was montmorillonite category with different base element like alumina, sodium and Iron as major composition. Trials with different size ranges like 1.7mm, 2mm, 2.7mm and powder form was carried out. The clay catalyst was purchased from Local Suppliers.

C. Experimental Setup

The cracking process is carried out in reactor set up shown in figure 2. Reactor with capacity of 1kg of feed is used. The reactor is uniformly heated across its surface by a band heater. The detailed design of the reactor system is available in Roopa et al. [18]. The temperature within the reactor is measured with the help of a k-type thermocouple which is connected to a PID controller with 2 phase power supply and contactor with 3 phase power supply. To avoid heat losses insulation jacket is used with glass wool stuffing in annulus space. Reactor head is a hemispherical dome connected with an outlet, made of GI pipe which is directly dipped in open jar for quenching where condensed oil is collected as supernatant.

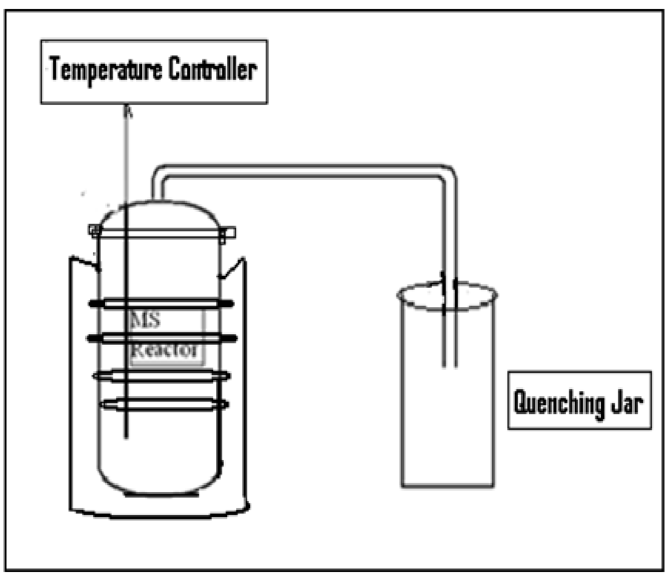

Fig.2. Experimental Setup

D. Operating Condition

Trials were carried out with different feed like only polypropylene (PP), low density polyethylene (LDPE), linear low density polyethylene (LLDPE) and combination of LDPE and PP. In all trials the catalyst to feed ratio is maintained as 1:4 (weight basis). The reactor is gradually heated to attain temperatures as high as 420-4500C. Melting of plastics is observed at 1210C (LDPE) and 1500C (PP). Total duration of processes including loading and unloading is 4-5 hrs. The vapors obtained are directly quenched in ice cold water. Later oil is separated using separating funnel.

The oil collected from all processes carried out like PP, LDPE, LLDPE and LDPE +PP are Yellow, brown and dark brown in color with 60-65%, 70-72%, 60-62% and 60% yield (Wt. basis) respectively.

E. Analysis

Product oil obtained is subjected to analyze physical and chemical properties such as density, viscosity, flash and fire point using Penske Marten apparatus and calorific value by Bomb calorimeter. Functional groups are analyzed by using FTIR

III. RESULTS AND DISCUSSION

- Physical Analysis of the Oil Obtained By Different Trials:

Physical properties	**Oil From**			
	Polypropylene	**LLDPE**	**LDPE**	**LDPE + PP**
Color	Yellow (turns dark with time)	Brown	Dark brown	Dark brown
Density kg/m3	779.77	770.22	730	790.82
Flash point 0C	46	52	52	60
Fire point 0C	56	73	64	82
Calorific Value cal/gm	10241	10742	9390.0	10002

Table 1: Physical Properties of Oil Sample

- FTIR Results

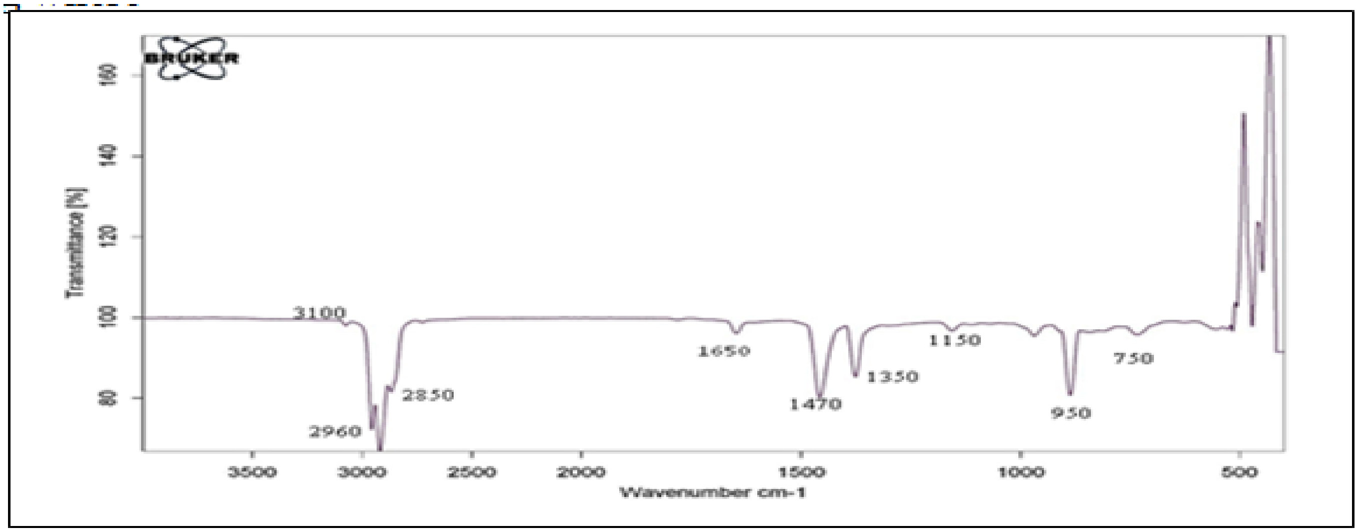

Fig.3. FTIR Analysis for Polypropylene.

Peak	Wave no(cm^{-1})	Functional Groups
1	3100	H-NH
2	2960	C-CH_3
3	2850	C-CH_3
4	1650	Amines
5	1470	CH_3
6	1350	CH_3
7	1150	Acetates
8	950	CH=CH(Trans)
9	750	CH=CH (cis)
10	650	CH=CH (cis)

Table 2: Data Of Peaks In Figure and the Representative Functional Groups

The following table 3 consolidates FTIR analysis showing functional groups present in oil from other trials

	Oil from					
	LLDPE		LDPE		LDPE + PP	
Peak	Wave no (cm^{-1})	Functional groups	Wave no (cm^{-1})	Functional groups	Wave no (cm^{-1})	Functional groups
1	2956.11	C-H	3390.29	=C-H	2915.01	C-CH_3
2	2921.75	C-H	2927.02	CH_2/CH_3/CH	2919.05	C-CH_3
3	2850.82	C-H	2854.95	CH_2/CH_3/CH	1647.07	Amines
4	2557	O-H	2147.2	C-H	1457.07	CH_3
5	1688.43	C=O	1735.17	C=O	1378.3	CH_3
6	1453.39	C=C	1650.79	C=O	1156.28	Acetates
7	1290.23	C-O	1462.79	CH_2	988.02	Secondary cyclic alcohols
8	1127.57	C-O	1377.4	CH_2	888.72	C=CH_2
9	772.38	C-CH_2	1042.32	C-O	734.51	CH=CH (cis)
10	707.41	C-Cl	924.44	C-O	522.99	CH=CH (cis)

Table 3: Data of FTIR Peaks and functional groups for other oil samples

From the figure 3 FTIR analysis for the Polypropylene oil sample, different functional groups showed. The results confirms that the oil sample contains NH2, C-CH_3, CH_3, CH=CH (Trans) and CH=CH (cis) groups. Wave number and functional groups for oil from LLDPE, LDPE & combination of LDPE and PP mixture (Table 3) showed the presence of C-H, C=O,C=CH_2, Acetates, Amines, Sec. cyclic alcohols, CH_3, C-CH_3, CH=CH (cis) groups. All the FTIR results obtained compare with commercially available fuel oil and it's found that the functional groups present in oil obtained in our processes shows similarity.

IV. CONCLUSION

Waste plastic can be converted into fuel range hydrocarbon using clay as catalyst. The conversion takes place in liquid phase reaction technique with yield of 60-72% (wt basis). The FTIR diagram and tables shows presence of paraffinic, oligomeric compounds present in oil sample. Physical properties show that oil from waste plastic is in range of commercially available gasoline to diesel range.

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