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FULL LENGTH ARTICLE

Clay Catalyst in PP and LLDPE Conversion to Fuel

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ABSTRACT

Waste plastic conversion into value added product is an advancing area of research. Many catalysts are involved in converting waste plastic into fuel range hydrocarbon. Clay catalysts being unique with their properties give good result in restricting waste plastic into liquid oil than light gases. Current work describes involvement of Bentonite catalyst in conversion of Polypropylene (PP) and Linear Low density polyethylene (LLDPE) in a batch reactor. The reactor used is batch type with 1kg feed capacity with insulation jacket. The catalyst feed ratio of 1:4 is optimized with fuel oil yield of 65-70 % (wt). The physical and chemical analysis shows sample is in range of olefinic and paraffinic compounds
Keywords: Bentonite, PP, LLDPE, clay catalyst, waste plastic degradation, pyrolysis

INTRODUCTION

Plastics are basically long chain polymeric material derived from petroleum and petrochemical resources; in fact these are solidified oil. They therefore have high calorific value. Simple chemical recycling can give value added product which can help in energy sector to compensate conventional ways to generate energy directly or indirectly. Chemical recycling of waste plastic comprises of Gasification, thermal Pyrolysis, catalytic pyrolysis, hydrolysis etc., among theses pyrolysis both thermal and catalytic pyrolysis gaining importance both with ease of process and good yield. Many catalysts are used for converting plastic into oil namely Alumina-silica[1] , zeolite based such as ZSM-5, Hy&Hb[2] activated carbon, granulated charcoal and calcium oxide[3]; Fe_2O_3, Pd/Al_2O_3[4], commercial catalyst Ecat-I[5]. Clays are naturally occurring aluminosilicates having sheets structure. Clays and zeolite are having similar crystalline structure with aluminosilicates composition; they are differing in pysico-chemical properties. Clays are widely used as catalysts and catalyst supports in alkylation, dimerisation and polymerization reactions and as a component in carbonless copying papers [6]. The different source clays are Kaolinite, smectite, vermiculite, illite, palygorskite and other minerals. As most of the source clays are naturally occurring materials, they typically contain minor to significant amounts of other mineral impurities [7]. Certain clay minerals used in specific applications because of the physical and chemical properties depends also on their structure and composition. The structure and composition of kaolins, smectites, and palygorskite and sepiolite are very different even though they have octahedral and tetrahedral sheets as their basic building blocks. However, these arrangement and composition of these sheets account for major and minor differences in the physical and chemical properties of these three types [8]. Montmorillonites are clay minerals broadly employed in industrial processes. These minerals stand out by some properties as great specific surface area (S) and high thermal stability (T), among others, which make them effective as adsorbents, catalytic support, for foundary materials and as viscosity modifiers [9]. The mineral names in smectite group which are most commonly used are Na- montmorillonite, Ca-montmorillonite, sponite (Mg), nontronite (Fe), and hectorite (Li). The rock in which these smectite minerals are dominant is Bentonite.the term bentinite was defined by Ross & Shannon as clay altered from glassy igneous material, usually a tuff or volcanic ash. Structure of this material is formed from two tetrahedral sheets with Si(IV) as a central atom and one octahedral sheet containing Al(III), which can be substituted by Fe(III) or/and Mg(II). This kind of structure exhibits cation exchange properties, swelling ability, plasticity, cohesion, compressibility, adsorptive properties and catalytic activity [10].

MATERIAL AND METHODS:

Experimental set up:

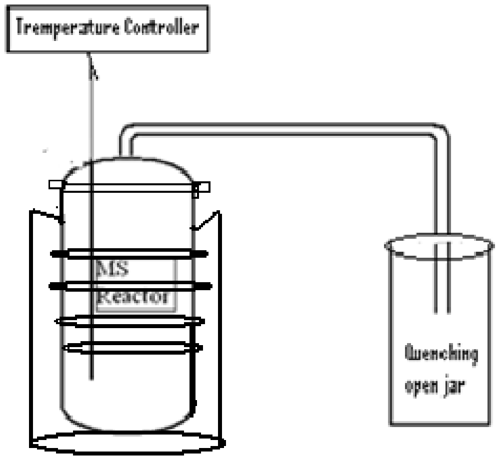

Figure 1. Experimental setup

The cracking process is carried out in reactor set up shown in figure 1. Reactor with capacity of 1kg of feed is used. The reactor is uniformly heated across its surface by using a band heater. 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. Insulation jacket is used to avoid heat losses with glass wool stuffing in annulus space. Reactor head is connected with an outlet, made of GI pipe which is directly dipped in open jar for quenching where condensed oil is collected as supernatant.

MATERIALS

Segregated waste plastics like Polypropylene (PP), LLDPE (Grade-1 plastic into granules having linear structure of 3-5mm) are collected from municipal waste and shredded into small pieces by shredder in SembCorp shredding unit and extruder at MDP Blenders, Penya (Bangalore) respectively.

Catalyst used:

Natural Bentonite is used as catalyst in present work along with base like Sodium, aluminum form of different size. The catalyst was procured from Sai Dhurga Enterprise, Rajajinagar (Bangalore).

Operating condition:

Trials were carried out with different feed like only PP and LLDPE. In the trials different catalyst to feed ratio is maintained such as 1:3, 1:4, 1:5(weight basis). The reactor is gradually heated to attain temperatures as high as 430-450^0 C. Melting of plastics is observed at 121^{0}C (LLDPE) and 150^{0}C (PP). Total time duration of processes is 3 hrs. The vapors obtained are directly quenched in quenching jar containing ice cold water.

Analysis:

Oil obtained is inspected and various tests are carried out to determine the physical properties like specific gravity, density, viscosity (Redwood viscometer), flash point and fire point (Penske martin Apparatus), Calorific (Bomb calorimeter) and functional group analysis (FTIR).

RESULTS AND DISCUSSION:

Physical Analysis

The catalyst to feed ratio of 1:4 gave very good results compared to other two. Hence the results showing here are obtained from the catalytic conversion. The oil samples were analyzed for their physical properties and the results obtained are listed below.

Table 1: physical properties of oil samples

Physical Property	Oil from PP+ 2 mm catalyst	Oil from LLDPE+ 2.7mm	Oil from LLDPE+ 1.7mm
Color	Yellow (turns dark with time)	Dark Brown	Dark Brown
Density(kg/m^3)	779.77	769.89	770.22
Flash Point(^{0}C)	46	51	52
Fire Point(^{0}C)	56	73	73
Calorific value cal/gm	10241	10742.0	10742.0

FTIR results:

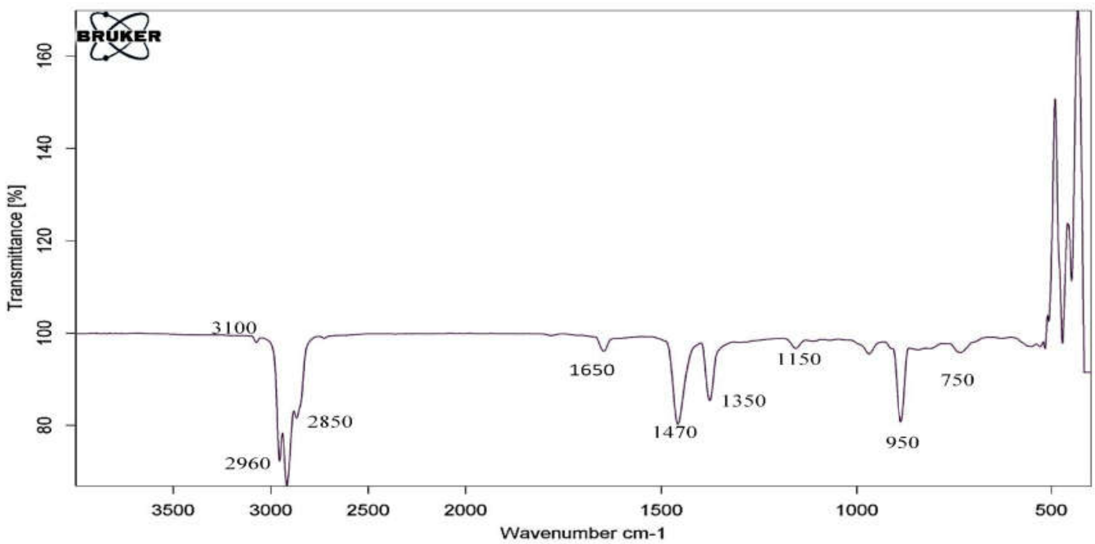

Figure2. FTIR analysis of oil obtained from PP

Table 3: Data of Peaks in Figure and the representative functional groups for oil from PP

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)

From the figure 2 FTIR analysis for the oil sample from Polypropylene, different functional groups showed response at unique wave number ranges. The results confirms that the oil sample contains H-NH, C-CH_3, CH_3, CH=CH (Trans) and CH=CH (cis) groups.

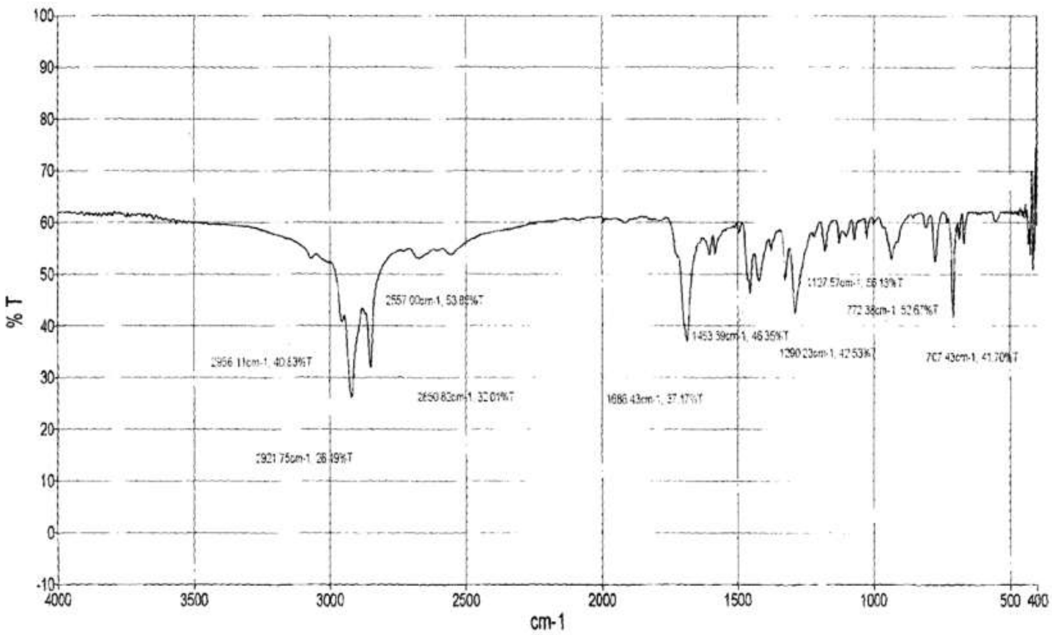

Figure3. FTIR analysis of oil obtained from LLDPE

Table 3: Data of Peaks in Figure and the representative functional groups for oil from LLDPE

Peak	Wave number(cm^{-1})	Functional Groups
1	2956.11	C-H
2	2921.75	C-H
3	2850.82	C-H
4	2557.00	O-H
5	1688.43	C=O
6	1453.39	C=C
7	1290.23	C-O
8	1127.57	C-O
9	772.38	C-CH_2
10	707.41	C-Cl

From the figure 3 FTIR analysis for the oil sample from LLDPE, different functional groups showed response at unique wave number ranges. The results confirms that the oil sample contains C-H, C=O, C=C, C-CH_2 and C-Cl groups.

CONCLUSION

Waste plastic can be converted into fuel range hydrocarbon using clay (Bentonite) as catalyst. The conversion takes place in liquid phase reaction technique with yield of 65-70% (wt basis). The optimum parameters for the process are 1:4 catalyst feed ratio, temperature in range of 420-450^{0}C, and total time for the process to complete is 3 hrs. 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.

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