Thermo catalytic Degradation of Waste Polythene into lubricants using Zeolite

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Abstract: Waste polythene primarily in the form of used polythene bags, comprises of most of the plastic pollution caused in India. Many processes have been developed to combat this issue which includes pyrolysis and catalytic cracking. This paper states an experiment that was carried out using catalytic cracking using Zeolite (ZSM-5). The catalyst in presence of heat helped to break down the polymer molecules. The experiment gave a product which consisted of 80% grease. The obtained product can be used for various industrial and domestic applications where lubrication is required. The recyclable nature of the catalyst makes this process efficient, affordable as well as environment friendly.

Key Words: polythene, pyrolysis, catalytic cracking, Zeolite, grease.

Introduction:

Pollution due to waste plastic has been a very large issue in countries like India and China in the Asian region. India generates 5.6 million tons of plastic waste annually. In this large plastic waste there is a large share of the metro cities [4].

PLASTICS CONSUMPTION IN INDIA

S.NO	YEAR	CONSUMPTION (Tones)
1	1996	61,000
2	2000	3,00,000
3	2001	4,00,000
4	2007	8,500,000

Table1.1: Plastic Consumption In India

(ASSESSMENT OF PLASTIC WASTE AND ITS MANAGEMENT AT AIRPORTS AND RAILWAY STATIONS IN DELHI, CBFC, 2009)

Indian capital New Delhi generates almost 690 tonnes of plastic everyday of which only 40 percent gets recycled. The remaining plastic waste finds its way into the rivers, roads and drains.[2] The plastic pollution in China has been so severe that it has led to harmful effects on the oceans. The plastic wastes clog in the oceans causing disturbances to the aquatic civilizations [3]. The major contents of these plastic wastes include polythene bags. Metros like Delhi in India are even thinking about banning these plastic bags forever.[1]

Fig.1.1 An Indian Boy collecting plastic waste (Reuters)

Even though these bags are recyclable, the process of recycling is not always environment friendly and is also very expensive. Thus, many small scale traders in order to avoid these cumbersome processes end up burning or throwing away these bags in waste dumps or water bodies. Such activities in fact lead to more pollution. These bags are mainly made up of Polyolefins (HDPE, LDPE and PP). In this experiment we have used LDPE bags. These are recyclable compounds.
Recycling of plastics by using them as alternate fuels reduces the energy costs but also reduces the CO2 emissions. Pyrolisis is normally used to break down the polymers. Pyrolisis carries out degradation of polymers in absence of oxygen. However, in order to save the expenses as well as increase the simplicity of the task this experiment we did not use pyrolisis. Instead, thermo catalytic degradation using a catalyst was carried out. This process is much easier as well as inexpensive to carry out.

In this research, waste polythene bags which are normally found in households were used. Only transparent bags were only used in order to maintain uniform product composure. The plastic bags contain polymer molecules which required to be broken down for degradation. This task is carried out by Zeolite –ZSM 5. In presence of heat at a temperature of 500-600 ^{0}C, this catalyst breaks down the polymer in order to generate wax like product.

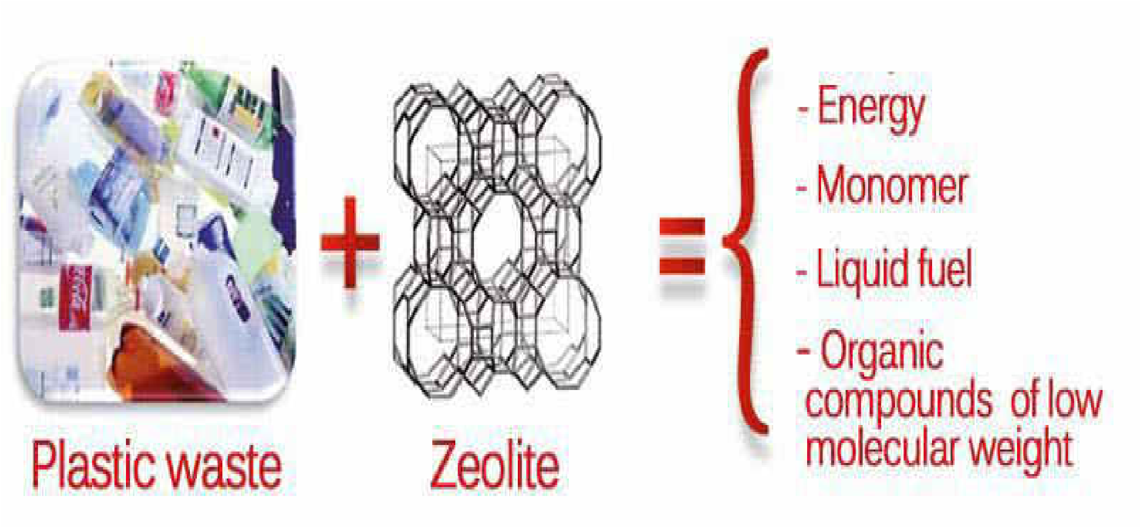


Fig 1.3. The main process

Zeolites are natural volcanic minerals that are mined in certain parts of the world. When volcanoes erupt, molten lava and thick ash pour out. This material was named "zeolite", which stems from classical Greek, where ζεω (zeo) means "to boil" and λίθος (lithos) means "stone". [11]. The elementary building units of Zeolite are SiO4 and AlO4 tetrahedra. Adjacent tetrahedra are linked at their corners via a common oxygen atom, and this result in an inorganic macromolecule with a structurally distinct three-dimensional framework. (zeolites and catalysts) .

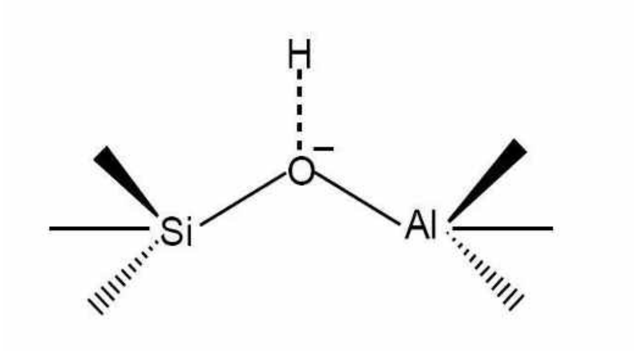


Fig 1.4 Structure of Zeolite [11]

There are various types of Zeolite samples. They are known as ZSM, 4.9 MOR, 9.9 MOR, 16.7 MOR, 27 BETA, 110 BETA, 10.5 BETA and Y. The 110 BETA has the best Si/Al ratio whereas Y has the best micro pore volume (cm^3/g) [10]. The sizes of the ZSM-5 particles have a strong effect on the changes in product yields and gas and gasoline compositions. Alkali-treated ZSM-5 zeolites produce higher yields of light olefins compared to untreated zeolites. The zeolite microspore's are of molecular size which give them adsorption, catalytic and ion exchange properties which are very important. The four main characteristics of zeolites are their tetrahedral framework, their cavity system, and the presence of water and charge compensating cautions in well-defined crystallographical positions.[5]

The reaction time depends on the amount of heat provided. In this experiment, the heat was provided through a regular laboratory LPG burner so the initial reaction took almost 6 hours. However, the major advantage of using this catalyst is that it is recyclable. The remains after the initial reactions were retained and then used again for another reaction. The products obtained were satisfactory even with the recycled catalyst.

Methodology:

The set-up of this experiment constituted of regular laboratory apparatus. The apparatus used were as follows

A. *APPRATUS*
   1) Round Bottom Flask
   2) Burner
   3) Stirrer
   4) Condenser
   5) Waste Polythene Bags
   6) Zeolite ZSM-5
   7) Weighing machine
   8) Thermometer
   9) Beaker
   10) Tripod
   11) Iron Mesh

B. CONSTRUCTION

This experiment was carried out inside the round bottom flask. Initially the round bottom flask was placed on tripod using iron mesh. Burner was placed below the flask to provide continuous heat. The condenser was attached at the top of the flask with the help of a rubber cork. The arrangement was set up in a non-windy atmosphere to avoid the loss of burner flame. Thermometer was used to measure temperatures at certain intervals of time.

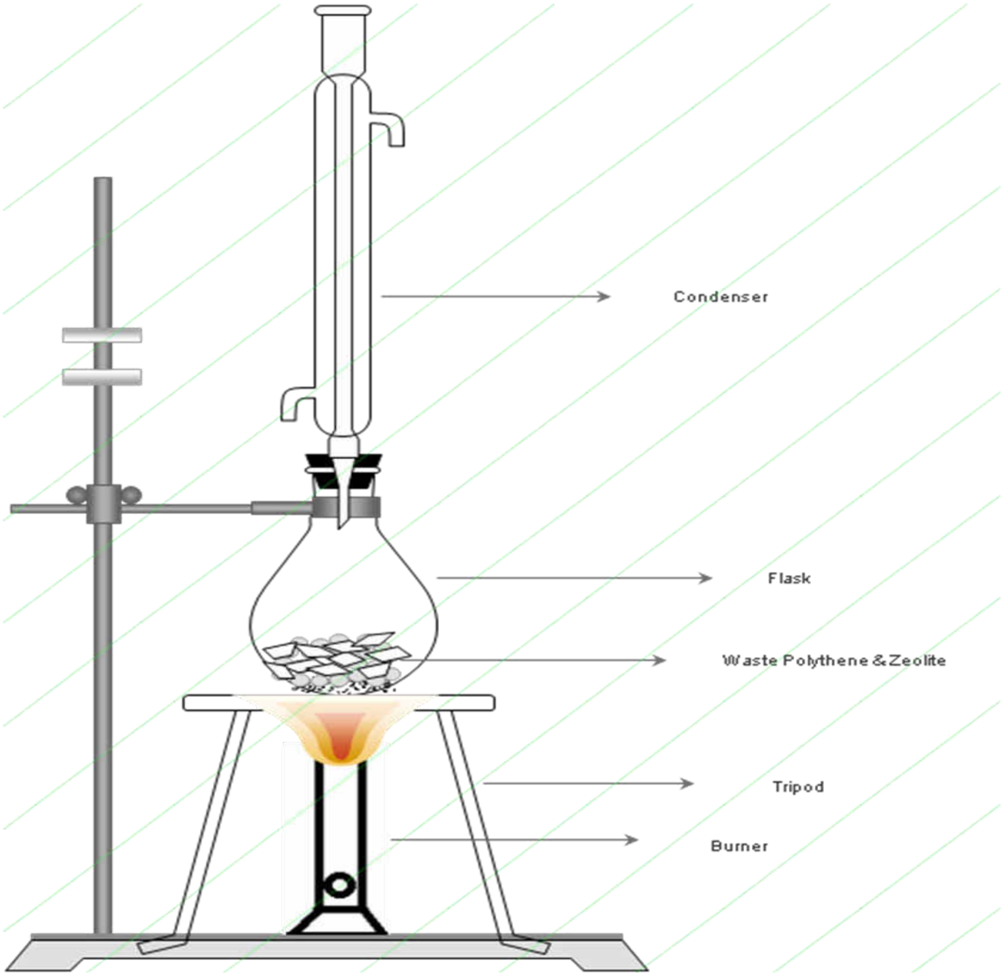


Fig 2.2.1: The experiment arrangement

C. WORKING

Firstly, 10 grams of plastic bags were added into the round bottom flask. Post the addition of the bags, the burner was turned on and the heat supply began. As the temperature reached 120 0C, the polythene bag pieces began to melt. After 30 minutes, 2.17 grams of weighted Zeolite ZSM-5 in amorphous form was added to the reaction. The mixture was well stirred using a stirrer. The catalyst thus began to carry out its job of breaking down the polymer. The following equation explains the process:

Chemical Reaction:

(C2H4) n + (Na2, Ca, Mg) 3.5[Al7Si17⇒48].32(H2O) C_nH_{2n+2} (1)(Polythene) (Zeolite) (Wax)

The condenser was used to provide cooling was well as stop the fumes from going into the atmosphere. By inhibiting the passage of fumes into the atmosphere, this process becomes more eco-friendly. The mixture was observed at regular intervals of time. The mixture began to change its color and consistency as the temperature and time increased. After 6 hours, the temperature reached 500 ^{0}C and the mixture had an appearance of boiling liquid. The heating was stopped and the mixture was collected in a glass beaker. The mixture was allowed to settle at the room temperature. After weighing, the mixture was found to be of 6.5 grams. When the mixture achieved room temperature, it was in a soft wax form. There was some grayish residue inside the flask. This residue consisted of the catalyst. For the next reaction, only 1.7 grams of catalyst was added and the results were still satisfactory. Hence, the reusability of the catalyst was also established during the course of this research. Furthermore, the advantage of this reusable nature of the catalyst was that the reaction time also reduced. Hence, the reaction with reused catalyst was much quicker than the first reaction.

Results:

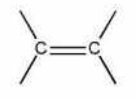
This research initially included various experiments using different catalyst forms. However, by considering the quality of product, the amorphous Zeolite ZSM-5 was found to be the most appropriate catalyst for the research. There were 3 main reactions carried out. The catalyst was reused for the final 2 reactions. The following table includes the results.

Sr No.	Polythene weight (grams)	Catalyst used	Catalyst weight (grams)	Reaction time (hours)	Product weight (grams)
1	10	Zeolite (Powder form)	1.7	6	6.5
2	10	Reusing from previous reaction	3.5	3	5
3	10	Reusing from previous reaction	3.7	2	7

Table 3.1: Reaction Table

In Mrs. Neeta Jhungare's study [8], spectral analysis was used to confirm the structure and identity of compounds obtained. Infrared spectra were scanned on "Perkin –Elmer-577" spectrophotometer. The Proton Magnetic resonance spectra recorded on "Perkin-Elmer R-32" in CdCl3 using TMS as reference. The UV-vis spectra were recorded in chloroform on "Perkin-Elmer 202" spectrophotometer. [8]

1) From the spectral analysis carried out at R.S.IC, I.I.T. Bombay the spectral data of compound was as follows:

Region (1/cm)	Frequency	Intensity	Correlation
3100-3000	2930.7	S	 Stretching
	2859.4	S	-CH2 stretching
1500-1400	1469.9	S	C-H stretching
900-800	914.3	S	C-C open chain

2) Spectrum No.2 showed the absorption peaks as follows

Chemical shift in δ	Nature of peak	No. of protons	Types of protons
5.4	M	10	Due to alkyl group
7.25	S	3H	CH2=CH2

3) The UV-vis spectrum of the compound spectrum 3 showed max a 224 nm.

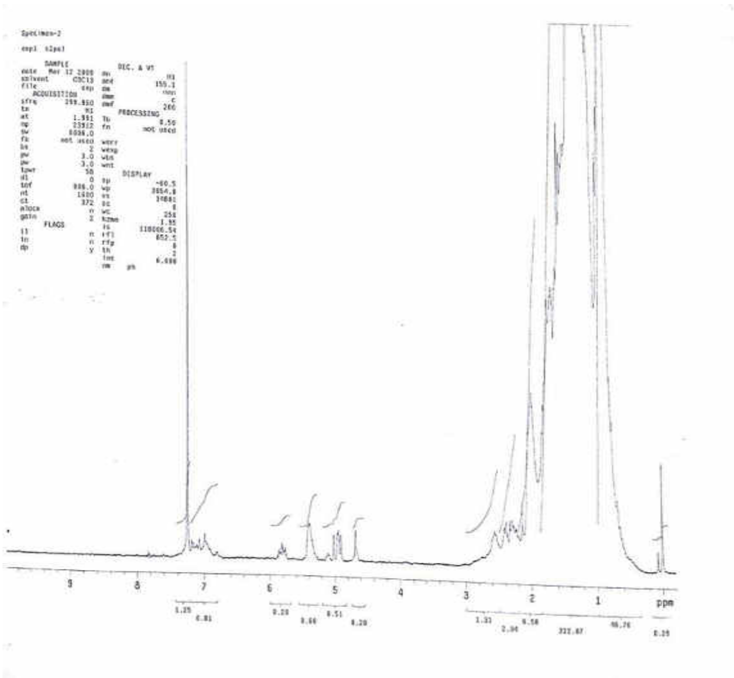


Fig 3.1.The NMR spectra

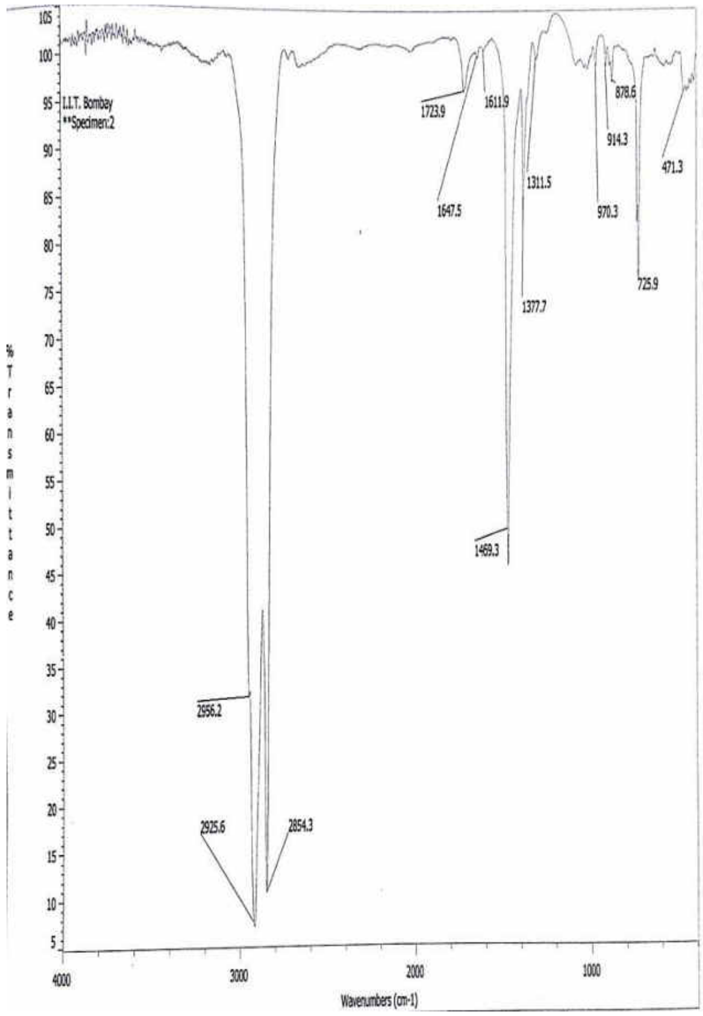


Fig 3.2The IR Spectra

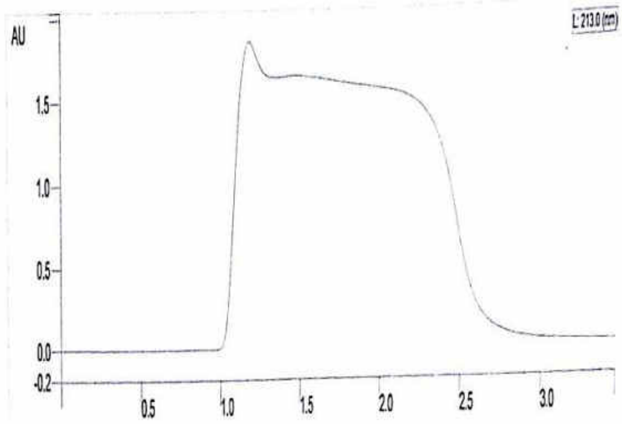


Fig 3.3 UV Spectra

The actual obtained product looked like the following figure:

Conclusion:

The summary of the results of thermo catalytic degradation of waste polythene are as follows

(1) The Zeolite ZSM-5 was the most appropriate catalyst to break down the polymer molecules of the polythene bags as it was found to be reusable giving a 70-75% yield.
(2) Reusability of the catalyst led to less reaction time as the reaction time decreased with increase in the reuse of catalyst.
(3) This process is more efficient than pyrolysis as the reaction time, cost and complexity are low.
(4) As the fumes are condensed and not allowed into the atmosphere, this process is totally environment friendly.
(5) The structures confirmed by IR, NMR and UV spectra are close to that of lubricants.

Therefore, by considering the stated parameters we can suggest that the process can be satisfactorily used to convert waste polythene to useful industrial product.

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