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Study of Catalytic conversion of plastic waste using different catalysts: focus on waste PVC

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***Abstract*— Waste plastic can, however, serve as a potential resource and, with the correct treatment, can be reused or serve as a fuel. The main aim of this paper is to modify the technologies of converting plastics into fuel and finding the better method to convert PVC into fuel. A case study is presented by taking different plastics together and to illustrate the role of different catalysts (Fe_2O_3, $CaCO_3$, SiO_2 and HZSM-5) with different temperature ranges. In contrast with other plastics PVC is non biodegradable and has a very high chlorine content. However chlorinated pyrolysis products could influence the value of pyrolysis oil if they were to be used as fuels. So in the experiments using the pvc waste stream which contained fillers such as calcium carbonate in addition to PVC it was noted that the HCl produced from the pyrolysis of PVC can be neutralized insitu.**

***Index Terms*— waste plastic, PVC, zeolyte, HZSM-5, catalytic degradation.**

I. INTRODUCTION

The amount of waste plastic is increasing worldwide. mostly plastics are non biodegradable there is also problem associated with the disposal of them. Recycling of waste plastics into usable products can resolve the problem and economically helpful also. However many recycling methods are suggested and a lot of research has been conducted in which pyrolysis is the most effective and promising method. By using the suitable catalysts we can increase the yield of fuel generated. Along with that in the pyrolysis of pvc, HCl is formed due to presence of chlorine. And can contaminate the fuel and also create corrosion problems. By using fillers like calcium carbonate HCl is neutralised into inorganic chlorides, alleviating many of the concerns associated with HCl formation.

Plastics have a high calorific value (i.e., polyethylene 43 MJ/ kg, polypropylene 44 MJ/kg, polyvinyl chloride 20 MJ/kg), and their combustion can be an alternative to extracting them and convert them to usable form.

II. MATERIALS AND METHODS USED

Different types of virgin plastics with different catalysts are taken together and pyrolyzed. Polystyrene, polyethylene, polypropylene and PVC in granular form were taken from plastic technology department Kota polytechnic college and PVC in powdered form from two places Chemical store, Jodhpur and Borana industries, jodhpur. In one batch PVC pipe was also taken as feed. Fe_2O_3, SiO_2,zeolyteZn-ZSM-11 and HZSM-5 were taken as catalysts.$CaCO_3$ is taken with PVC for neutralisation of cl gas due to formation of HCl from this gas. Nitrogen was supplied to make bed fluidised.

III. EXPERIMENTAL

Catalytic conversion of plastic wastes implies several advantages over conventional pyrolytic methods. The most evident relates to the lower degradation temperatures at which degradation reaction takes place, which results in lower energy consumptions and higher conversion rates.However, an even more important aspect is the shape selectivity exhibited by some micro porous catalysts, which allows the process to be directed towards a narrow distribution of hydrocarbon products with a higher market value [20-23]. Another advantage mentioned in the literature resides with the inhibition effect of catalysts in the formation of some undesired species, particularly chlorinated hydrocarbons, an aspect of particular interest in plastic wastes contaminated with PVC residues.

Experiment was done in a fluidised bed reactor in various rounds. In every round feed to catalyst ratio was taken as 3:1 except for PVC. Firstly mixture of Polystyrene (PS) 150 gm and Polyethylene (PE) 150 gm was taken with HZSM-5 100 gm. This mixture is transformed mainly to liquid over modified zeolites H-ZSM-5 and Zeolyte Y. The conversion levels are almost complete between 400-450^oC. A single-pass reactor and atmospheric pressure was employed in next batch Polyethylene (PE) &Polypropylene(PP) with Zeolyte Y with temperature range from 400^0C to 450^0C.in third round Polypropylene& Polystyrene was taken with HZSM-5.temperature range was same as 2nd batch. Then PVC was taken with $CaCO_3$ andHZSM-5. PVC, calcium carbonate and HZSM-5 were taken 300 gm, 150 gm, and 100 gm respectively. Here the feed to catalyst ratio was taken 6:5 with temperature range 120^0C to 480^0C.in the reactor 2 fluidised bed were there on first bed feed was taken and on 2nd and lower bed catalysts.

Table 1 Temperature v/s Yield of PVC when taken with HZSM-5+$CaCO_3$were taken as shown in

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S.No.	Temp. (^{0}C)	%Yield liquid	Operation control
1	22-100	Nil	
2	100-160	Nil	Purging is started with N_2 at 5LPH at around 100^{0}C
3	160-235	Nil	Stopped for maintain the temp. around 275^{0}C
4	235-300	Nil	Set up is again started
5	300-330	2.33	First drop of gasoline range is measured
6	330-360	5.00	Stopped for maintain the temp.
7	360-385	10.00	Set up is again started
8	385-410	13.33	

figure 1.nitrogen wassupplied at the bottom of the reactor to make it fluidized due to its inert nature to the materials used.

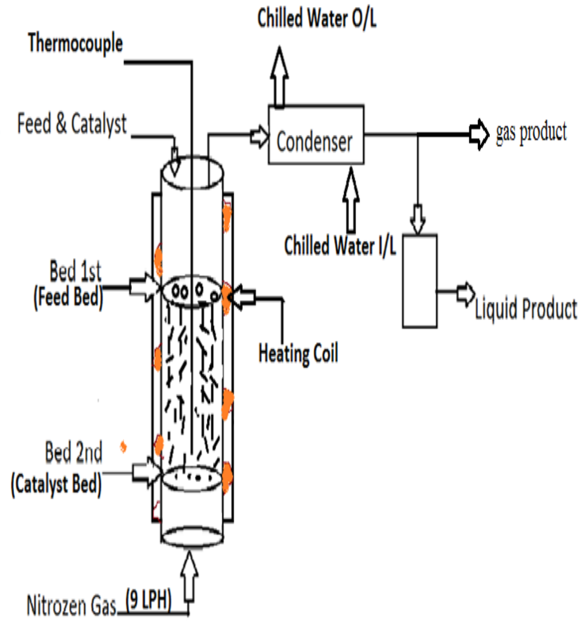

Fig.1 schematic diagram of catalytic degradation process

In last PVC was taken with Fe_2O_3 and $CaCO_3$ in fluidised bed reactor with feed to catalyst ratio taken as 3:1.temperatue range was 120^{0}C to 480^{0}C.

The setup of experiment was containing Fluidized bed reactor with 2 beds one for feed and one for catalyst, nitrogen distributer, a condenser, with nitrogen cylinder for supply of nitrogen.

IV. RESULTS AND DISCUSSIONS

HZSM-5 with mainly micropores showed the highest liquid yield. The catalyst containing zeolite enhanced the production of aromatic components. Temperature for de-chlorination of PVC is 270^{0}C.

Table 2 Temperature v/s Yield of PVC when taken with Fe_2O_3

S. NO.	Temp. (^{0}C)	%Yield liquid	Operation control
1	22-100	Nil	
2	100-180	Nil	Purging is started with N_2 at 5LPH at around 100^{0}C
3	180-235	Nil	Stopped for maintain the temp. around 275^{0}C
4	235-302	Nil	Set up is again started
5	302-380	3.33	First drop of gasoline range is measured
6	380-420	6.66	Stopped for maintain the temp.
7	420-435	9.33	Set up is again started
8	435-445	10.66	

Table 3 % yield of fuel from different combination of plasticss

Type of plastic waste sample	Temp. range (°C)	% yield liquid
PS+PE+ HZSM-5	400-450	81.50
PE+PP+ zeolyte Y	400-450	85.33
PP+PS+ HZSM-5	400-450	82.00
PVC+$CaCO_3$	390-460	5.00
PVC+HZSM-5	330-445	11.66
PVC+Fe_2O_3	300-450	10.66
PVC+HZSM-5+$CaCO_3$	385-410	13.33

As the plastics except PVC are concerned they give better yield of liquid fuel in presence of catalyst. As far as PVC is concerned the yield is maximum with HZSM-5 and $CaCO_3$.

The liquid fuel obtained from PVC had the following specifications:

Table 4 Properties of fuel from PVC

Test type	Test results	Regular gasoline
Specific gravity at 28°C	**0.7254**	**0.7423**
Specific gravity at 15°C	**0.7365**	**0.7528**
Gross calorific value (cal g^{-1})	**11262**	**11210**
Net calorific value (cal g^{-1})	**10498**	**10460**
Aniline point°C	**28**	**48**
Appearance	**Light brown**	**Orange**
Viscosity @40°C	**5**	**+ or -20 %**
Flash point °C	**25°C**	**22 °C**
Density@ 15°C g/cc	**0.782**	**0.710-0.770**
Insolubles	**1**	**Nil**
Pour point °C	**< -20**	**< -20**
Cloud point°C	**<-20**	**<-20**
Ash content (wt %)	**<0.01**	**<0.01**

V. CONCLUSION

While the multiple applications of synthetic polymers are of considerable societal benefit, a build-up of polymeric waste can have a deleterious effect on the environment. Landfill or incineration does not represent best practicable environmental options when dealing with PVC waste. The Cl content must be removed in a controlled fashion as part of an overall recycling operation. Direct degradation of PVC in the presence of catalyst results liquid fraction with a significantly reduced Cl content. We got a good yield of fuel with polyethylene, polypropylene and polystyrene and less content of solid residue. In catalytic degradation of PVC we got fewer yields with different catalysts due to the presence of chlorine about 56% by weight. By using $CaCO_3$ the chlorine gas is absorbed and no HCl is formed during conversion and thus good quality of fuel and no harmful effects. We can convert waste PVC in usable products and by using more catalyst we can increase the yield too. And fuel from remaining waste plastics can be increased by using suitable catalyst.

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