Plastro Fuels from Waste Plastics by Thermal Cracking Catalysts

[PLASIV-H* & PLASIV-D*]

G.Manoj Kumar, R.Pavan Kumar (Asst. Professor) Department of Mechanical Engineering, Sri Sivani institute of technology, chilakapalem, srikakulam, A.p, India-532402. manojkumarganagalla26@gmail.com

Abstract: Plastic materials which cannot be recycled are usually dumped into Undesirable landfill. Worldwide almost 20% of the waste stream is plastic, most of which still ends up in landfill or at worst it is incinerated. Conversion of waste into fuel is one of the recent trends in minimizing waste plastic. In this project, catalytic pyrolysis of waste plastic has done in at anaerobic condition. Catalysts are commonly used in conversion of waste plastic into fuel, which are very helpful in thermal cracking of waste plastic. Commonly zeolite and silica alumina are used as catalysts. But these are very costly. So we are used similar propertied catalysts which are having low cost when to compare zeolite. The waste plastic is heated with the catalyst combinations [(calcium carbonate + sodium carbonate), (barium carbonate + magnesium carbonate)] up to temperature ranges from 280-350°c to produce the fuel. We maintained 4:1 optimum polymer to catalyst ratio for producing fuel. The output fuel samples have been investigated under various fuel property tests and results of catalytic combination fuel samples have compared with petrol, diesel, zeolite and silica alumina catalyse pyrolysis fuels. These output fuels are named as PLASIV-D*.

Index terms: - pyrolysis, catalytic pyrolysis, thermal cracking.

I. INTRODUCTION

Plastic is the high molecular weight organic polymer which can be moulded into desires shapes by applying on heat and pressure. The plastic lurks around in ecosystem for many years without degrading into its core elements carbon and hydrogen. Waste plastics are indispensable materials in the modern world and application in the industrial field is continually increases .In a new study published in science journal, researchers have quantified the amount of waste plastic entering oceans from coastlines of 192 countries. The study calculates that of 275million metric of plastic waste produced by 192 countries in the year 2010.In that of top 20 countries including India, account for 83% of all the mismanaged waste available enter to the ocean. India is the 12th in the list of 20 countries notorious for disbursing the maximum amount of waste plastic. With the available data, that one person generates 0.34 kg waste every day in India, of which 3% of plastic waste formation, India got 12th place. Overall 20% of plastic in the world is in still landfill. This percentage continuously increases day by day and they cannot recycle or conversion into any other form.

The plastic has achieved such an extensive market due to fact that it is lightweight, cheap, flexible, and reusable, do not rust or rot, and so forth. Because of this, plastics production has gone up by almost 10% every year on a global basis since 1950. Asia accounts for 36.5% of the global consumption and has been world's largest plastics consumer for several years. The major segment continues to be the packaging, which has accounted for over 35% of the global demand. The global production of plastics has seen an increase from around 1.3 million tonnes in 1950 to 245MT in 2006. At present 60,000 various types of plastics are available in the world. In that 6 types of plastics i.e., Polyethylene terepthalate, high density polyethylene, polyvinyl chloride, low density polyethylene, polypropylene, polystyrene are mostly available. Most of the waste plastics are available these materials. These all are belong to thermoplastic generation, so these all are recyclable and converted into any other form. At present, many researches are going on many countries on basis of waste plastic management. In that, conversion of waste plastic into useful fuel is the one of the technique followed by the many countries. This

technique involves the catalytic pyrolysis of plastic. Catalytic pyrolysis is a promising thermo chemical conversion route for lignocelluloses biomass that produces chemicals and fuels compatible with current, petrochemical infrastructure. Pyrolysis is defined as the irreversible anaerobic thermal decomposition at elevated temperature $(310+\,^\circ\text{c})$. While in the pyrolysis of plastics, catalysts are used. A catalyst accelerates a chemical reaction. It does so by forming bonds with the reacting molecules, and by allowing these to react to a product, which detaches from the catalyst, and leaves it unaltered such that it is available for the next reaction. In fact, we can describe the catalytic reaction as a cyclic event in which the catalyst participates and is recovered in its original form at the end of the cycle.

II. LITERATURE SURVEY

In the year 2000, catalytic degradation of pure polymers has done by LINY-H. He used acidic zeolite(HZSM-5,HMOR & HUSY) and non zeolite (silica alumina) as catalysts with the designed bed reactor. He has done systematic experiments carried out with several catalysts to reduce the reaction temperature, improvement the yield of volatile products and provide selectivity in the product distribution. He said that the catalyst deactivation in relation to chemistry has been developed.

In the year 2010, the research on pyrolysis of waste plastic into fuel in on the basis of catalyst ZSM-5 have done by FANG GAO. He has done various pyrolysis analyses on the polyethylene, polypropylene, polystyrene and plastic mixtures. He found that the heavy molecular weight hydrocarbons produced from the primary cracking can be further cracked into light molecular weight products through secondary cracking He said that the high temperature pyrolysis which effects on production and prevention of back flow of high temperature pyrolysis vapour is very important.

In the year 2012, MOINDDIN SARKER, MOHAMMAD MANUMOR, MOLLA, RAHMAN have done recycling of waste plastic into fuel on the basis of process temperature. They produced fuel without using any catalyst or extra chemical. They setup the melting point of high density polyethylene, low density polyethylene and polypropylene are 130,120 and 160 °c. They used 200°c as starting temperature for quick melting and to produce vapour faster. They setup condensing unit and collect fuel from that temperature. They can reduce the experimental cost by setup temperature limits and avoiding of catalysts.

In the year 2013, CHRISTINE CLEETUS, SHIJO THOMAS AND SONEY VARGHESE have done synthesis of petroleum based fuel from waste plastic on the basis of different catalysts. They are using silica alumina (SA1 & SA2), y zeolite, barium carbonate, zeolite and their combinations as a catalyst. They maintain 10:1 as a polymer catalyst ratio and maintain the temperature ranges in between 400 -500°c. This temperature is very suitable for producing the low density vapour fuels, which are effecting on good quality fuel which are having optimum fuel properties. While in the production, 64% of production cost accounted for only the catalysts. This is the one of the problem faced on that experimental analysis.

III. CRITICAL REVIEW

On the conversion process, commonly catalysts are used which are very helpful in thermal cracking of polymer. zeolite and silica alumina are best catalysts, but these are high cost which effects on production cost. If conversion of waste plastic into fuel can be done with similar property catalysts which are having low cost, the overall production cost will decrease. Maintaining of 4:1 optimum polymer to catalyst ratio which effects on good quality production output. Temperature also which effects on quality of the output, But overheating which effects on increasing of production cost. This can be overcome by setting out the temperature limits for the particular type of plastic when it produces vapour which is useful for forming fuel. By considering the above three factors (similar propertied low cost catalyst, polymer to catalyst ratio and temperature), we can get the good quality fuel within low production cost.

IV. THERMAL CRACKING OF WASTE PLASTIC

The chemical changes of plastics have been investigated in order to understand the cracking mechanism in the pyrolysis when the temperature rises above the decomposition temperature. Due to this temperature increasing,

the vibration of molecules gets intensive and small molecule will escape the object surface when the vibration is intensive enough to overcome the Vander Waals force, which is called evaporation .However, when the Vander Waals force induced energy is greater than the bond enthalpy between atoms in the molecule structure, the molecule will crack rather than evaporate. The cracking occurs at the most unstable bonds in the molecular structure. The stability of carbon bonds in then plastics varies with the carbon bond molecular structure and the order of stability of the hydrocarbons.



Temperature is one of the most important operating variables, since the temperature dominates the cracking reaction of the polymer materials. Not all of the polymer materials can be cracked by increasing the temperature. Based upon the temperature, thermal cracking of polymers occurs and its cracking limits of polymer are changes based on the temperature. The above figure shows an initiation reaction- Homolysis of a carbon-carbon bond. Homolysis is where the bond breaks so that each fragment has one electron. It reduces its bonding strength due to increasing of temperature.



V. MODEL LAYOUT OF EXPERIMENTAL SETUP

Fig.1: Experimental setup layout

Reactor: - It is a device for controlling and containing of reactions. The reactor type for the plastic pyrolysis significantly influences on the heat transfer rate, mixing of plastics with pyrolysis products, residence time and the reflux level of the primary products. Reactors can be classified into batch, semi-batch and continuous or classified based on types of reactor bed. Based on the heat transfer methods and flow patterns of the feedstock and products, the pyrolysis reactors can be classified into fixed bed reactor, fluidized bed reactor and screw kiln reactor. We are using batch type reactor. In this reactor we are placing waste plastic and catalysts before starting of pyrolysis. We are using carbon steel as a reactor material. It has a capability to withstand the temperature up to 1000°c. These reactor can be heated up to 350°c temperature for conducting the experiments. The penetration type thermocouple inserted inside the reactor. Reactor consists of vapour transferring pipe line and slag passing

pipe line. The generated vapour was passing out through the vapour transferring pipe line. We provided the heat from the bottom side of the reactor by using heating device. Based upon the temperature and inside pressure, transferring pipe valve openings are done in at the reactor.

Vapour transfering pipes:- These were placed at the top of the reactor and extended upto condensing unit. These are commonly used as tranfering pasagers for the vapour. These are made up of galavanizied iron material, which can withstand high temperature vapours. These pipes are cheap, light in weight and easy to handle & transport & easy to join.

Condensing unit:- It is very necessary to get fuel by condensing the low density vapours. The condensing unit consists of copper pipe and water cooled tub. These have been fixing like a indirect contact heat exchanger model. A copper pipe receives the vapour from the vapour transferring pipes with a high temperature. Whenever the copper pipe receives vapour, the temperature of the vapour reduces gradually due to the indirect cooling effect provided from the cool water on copper tube surface which will effects on formation of fuel droplets inside the copper pipe. These fuel droplets were collecting in a glass bottle.



VI. EXPERIMENTAL SETUP AND CATALYST COMBINATIONS

Fig.2: Practical experimental setup

CATALYST COMBINATIONS:	First combination catalyst	:	mixture of CaCO ₃ +Na ₂ CO ₃
	Second combination catalyst	:	mixture of BaCO ₃ + MgCO ₃
	VII. WORKING		

The small size waste plastic pieces and catalyst were placing inside the reactor with an polymer to catalyst ratio of 4:1 ratio. These are heated up to above 310°c temperature inside the reactor in at anaerobic condition. A thermo coupled pyrometer which is placed inside the reactor, which will gives inside temperature of the reactor. While in at the time of heating, thermal cracking of polymer can occurs inside the reaction reactor. This thermal cracking is based on the increasing of temperature, which effects on the output quality of a fuel. In the reaction chamber, vapours generation starts when at the temperature reaches to 200°c .when the vapour generation starts, we are condenses the vapour in the condensing unit. Condensing unit which are mainly used for reducing the

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temperature of the vapour, it will effects on phase transformation i.e., vapour to liquid. After condensing the vapour, fuel droplets can be formed in at the end of condensing copper tube pipe.

VIII. ANALYSIS REPORT ON PROPERTIES OF OUTPUT SAMPLES

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	S.No	Parameter	Sample 1	Sample 2		
	1	Colour	Yellowish Brown	Dark Brown		
	2	Odour	Unpleasant smell	Unpleasant smell		
-	3	pH	4.70	4.94		
	4	Turbidity (NTU)	34.1	27.9		
	5	Density (g/cc)	0.7423	0.7412		
	100	Flash point (°C)	32	28		
		The second s				
	7	Fire point ("C)	34	30		
	7 8	Fire point (°C) Viscosity (Centi stokes)	34 3.811	30 5.032		
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IX. COMPARISIONS OF VARIOUS FUEL PROPERTIES WITH OUR OUTPUT SAMPLE FUELS:

Fuels					
<u>Petrol</u>	<u>Diesel</u>	<u>Plastic</u> <u>fuel</u>	<u>Plastic</u> <u>fuel</u>	<u>Plastic fuel</u> <u>sample1</u> [PLASIV-H*]	<u>Plastic fuel</u> <u>sample2</u> [PLASIV-D*]

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Catalyst used	Crystalline zeolite	Crystalline zeolite	Zeolite catalyst	Silica alumina catalyst	Na ₂ CO _{3 +} CaCO ₃	$BaCO_3$ + $MgCO_3$
Fuel collected(ml)	-	-	110	145	120	125
Temp(°c)	150	150-350	450	450	310	310
Flash point(°c)	-43	52-90	<32	<32	32	28
Fire point(°c)	>-40	>55	36	34	34	30
Kinematic viscosity(cSt)	0.93-1.01	2.2-5.51	1.3700	1.3585	3.811	5.032
Dynamic viscosity(cp)	0.6-0.8	1.7-4.9	1.1829	1.2866	2.828	3.7297
Density(g/cm3)	0.72-0.79	0.81-0.89	0.8635	0.9471	0.7423	0.7412
PH value	5.5-5.88	3.6-5.6	-	-	4.70	4.94
Colour	Yellowish brown	Reddish brown	-	-	Yellowish brown	Dark brown
Odour	pleasant	pleasant	-	-	unpleasant	Unpleasant
Turbidity(N.T.U)	-	-	-	-	34.10	27.9
Calorific value(kJ/kg)	48000	44800	45150	41360	41000-44000	41000-44000

TABLE: 01

*** DISCUSSION:**

We are termed as the output fuels as two different names.

The output sample of plastic fuel of first type i.e., sodium carbonate + calcium carbonate catalytic pyrolysis fuel is termed as **PLASIV-H***. The output sample of plastic fuel of second type i.e., barium carbonate + magnesium carbonate catalytic pyrolysis fuel is termed **as PLASIV-D***.

These are having similar properties. They will show the same values when to compare zeolite catalysed fuel and silica alumina catalysed fuel. These fuels are obtained with cheap cost catalyst combinations when to compare zeolite and silica alumina catalysts and these have optimum polymer to catalyst ratio before thermal cracking. The pyrolysis temperature for fuels PLASIV-H* and PLASIV-D* are in at 310°c only. Densities of these two fuels are nearer to density of petrol. These are in the ranges of 0.7gm/cm3. The flash and fire points of these fuels are occurring in at room temperature and these values are very low when to compare diesel. The distillate fuel is an excellent fuel and can be further used for fuel pumps, Automobile engines, burners / stoves, Boilers, Hot air generators, Hot water generators etc.

CONCLUSION

i. A petroleum based new alternative fuels named as PLASIV-H* & PLASIV-D* have been produced from waste plastic materials.

- ii. Various fuel properties have been examined and compared to other fuels.
- iii. Similar propertied catalysts like Baco3, Mgco3, and Na2Co3 & CaCo3 are used in the place of costly catalysts like zeolite & silica alumina. These will effects on decreasing the overall production cost.
- iv. According to our research "Baco3, Mgco3,Na2Co3 & Caco3" catalysts showed similar effect on output fuel like zeolite and silica alumina catalysts, but only difference occurs while in the field of yield.
- v. Optimum polymer to catalyst ratio of 4:1 have been maintained and setting of temperature limits for thermal cracking which results to get a good quality fuel.

FUTURE SCOPE

- Quality fuel will be collect at condensing unit by maintaining its temperature at -15°c. Because the low density fuel vapour requires -15°c temperature to change its vapour phase into liquid. These low density vapours are cannot collect at room temperature as liquid fuels. As a result, high quality fuel we can loss at room temperature.
- ii. Plan to usage of coke as a catalyst, in the place of zeolite.
- iii. Plan to get high quality fuel in a continuous process without wasting any By-product up to slag also.

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