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Recycling Plastics to Automobile Fuel

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ABSTRACT

With the recent regulatory changes made by the Bharat Stage BS 4 complaint vehicles, the emission norms have been strengthened to certain limits by making further changes in the engine equipment's after BS 4 engines were launched in April 2017 in India. As per the Indian government policy laid by the Ministry of the Road Transport and Highways the diesel and petrol variant engines are going to minimize the production of petrol and diesel variant engines for general utility vehicle, and substitute the same with electric cars upto 2020. But as the mechanical power is considered the internal combustion engine provides more efficiency than electric car. Also the stringent rules and regulations on the usage of plastics, have lead the recycling of the plastics and producing automobile fuel as an substitute to the usage of the diesel and petrol respectively.

Key Words: Plastic, Pyrolysis, Recycle, pyrolyzed fuel

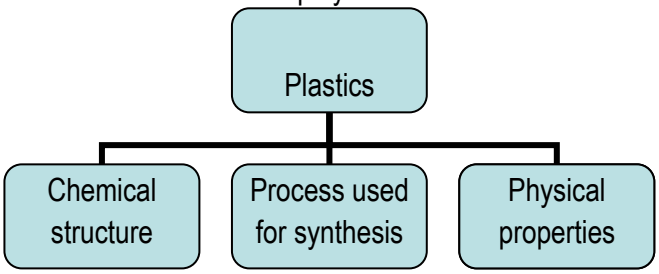
INTRODUCTION

According to the IUPAC plastics is defined as the material that consist of wide range of synthetic or semi-synthetic organic compounds that are malleable and they can be molded into solid objects. Plastics are the organic polymers of high molecular mass and they also contain other substances too. Plastics are synthetic and they are derived from petrochemicals, there are variety of variants which are made from renewable materials such as polylactic acid which are further derived from corn or cellulosics from cotton linters. Plastics are low cost and due to ease of manufacture and versatility they are used on large scale including plastics carry bags. Nowadays they are used widely to the substitute traditional materials such as wood, leather, glass and ceramic respectively.

The main use of the plastics is in packaging the goods and in building applications such as piping, plumbing or vinyl siding. Other applications includes automobiles, nearly 20% of automobile body consists of plastics. Plastics applications also include toys and furniture accounting for more than 45%. Another major application of the plastics is in medical field in many of the implants surgery plastics are used up to 20 % with composite materials, where reshaping is major parameter. In early 20th century due to environmental concerns as the rate of decomposition of plastic is slow, many countries have strengthened the law against the use of the plastics on major scale.

HISTORY OF PLASTICS

The first fully synthetic plastic was bakelite, which was invented in New York in year 1907 by Leo Baekeland who coined the term 'plastics'. Most of the plastic components contain organic polymers. Plastics consist of chains of carbon atoms with the addition of oxygen, nitrogen and sulfur respectively. To change the major properties of plastics many molecular groups are added to form the monomer or polymer chains.



Plastics are broadly classified into three categories:

1. According to the chemical structure.

Polymers play a major role in the chemical structure of the classification of plastics. These groups include acrylics, polyesters, silicones, polyurethanes and halogenated plastics consisting of halogen elements.

2. According to the process used for the synthesis of plastic.

The classification based on the process of synthesis includes condensation, poly addition and cross- linking.

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3. According to the physical properties.

The physical properties of plastics include hardness, tensile strength, density and resistance to heat and glass transition temperature.

4. Other

The other classifications of plastics include thermoplastics and thermo sets, biodegradable plastics and engineering plastics.

CONTENTS OF PLASTICS

1. POLYMERS.

Thermo set and thermoplastics are the two main types of polymers. Thermo sets or thermosetting polymers can be melted and it can take a shape once there are solidified.

Thermoplastics are the polymers that when heated, do not undergo chemical change in their composition and it can be moulded again and again.

2. AMORPHOUS AND CRYSTALLINE PLASTICS

Amorphous plastics consist of polystyrene and its co-polymers such as polymethyl methacrylate.

Whereas crystalline plastics consists of polyethylene, polypropylene, polyvinyl chloride, polyamide nylons, polyesters and some of the polyurethanes respectively.

3. CONDUCTIVE POLYMERS

Conductive polymer consists of polyacetylene and conductive materials like copper, aluminium etc.

4. BIODEGRADABLE PLASTICS AND BIOPLASTICS

Biodegradable plastics consist of additives which enhance biodegradation such as starch powder to allow the plastic to degrade quickly.

5. BIOPLASTICS

Bio plastics consist of the renewable plant material such as cellulose and starch and also different petrochemicals.

APPLICATIONS OF PLATICS

The common applications of plastics are as follows:

1. Polyamides (PA) or Nylons -Fibers, Toothbrush bristles, tubing, fishing line etc
2. Polycarbonate (PC) - CD's, eye lenses, riot shields etc
3. Polyester (PES)- Textiles and fibres
4. Polyethylene (PES)- Plastic bottles and carry bags.
5. Polypropylene (PP)- Bottle caps, drinking straws, plastic containers etc
6. Polystyrene (PS)- Food containers, cups, cutlery etc.
7. Polyurethanes (PU)- Cushioning foams, thermal insulation foams, printing rollers etc.
8. Polyvinyl Chloride (PVC)- Plumbing pipes, shower curtains, window frames and flooring.
9. Polyvinylidene chloride (PVDC) -Food Packaging.

PROCESS OF DEGARADATION

Most of the plastics are durable and degrade very slowly, as their chemical structure resist the process of degradation. In year 1975 a Japan based team studying on the recycling of the plastics studied that a ponds containing waste water from nylon factory consist of *Flavobacterium* that digested the by products of the nylon 6, such as the linear dimer of 6-aminohexanoate ,whereas Nylon 4 can be degraded by the strands of pseudomonas species found in sludge. Several species of soil fungi can consume polyurethane. This includes Pestalotiopsis that consume polyurethane by aerobic reaction respectively.

Methanogenic consortia degrade styrene using a carbon source. Microbial communities isolate from the soil samples and mixed with the starch can degrade polypropylene. The various fungus like *Aspergillus* fumigates degrades PVC. *Acinetobacter* can degrade low molecular weight polymer. Several different species of yeasts, bacteria and algae can degrade various high and low density polymers.

ENVIRONMENTAL EFFECTS BY PLASTIC USAGE

- Climate Change

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The excess use of the plastics makes the excess use of the petroleum products used for the manufacture of the plastics. Due to increase in carbon emission there is a major loss to the climate.

- Production of plastics

For the production of plastics crude oil requires minimum of 62 MJ/Kg to 108 MJ/Kg of energy requirements. Thus for the production of the plastics lot of amount of energy is been utilized which causes loss of many renewable as well as non-renewable respectively.

- Incineration of plastics

Due to burning of the plastics at above 850 degrees Celsius it emits toxic furans which are carcinogen in nature and can cause various cancers.

- Pyrolytic disposal

Pyrolysis of plastics can lead to the formation of hydrocarbons.

- Recycling of plastics

Generally of plastics is a time consuming phenomenon. The greatest challenge in the recycling of the plastics is sorting of plastics which is man power consuming and requires high man power.

The list of the recyclable plastics is as below:

1. Polyethylene terapthalate. (PET)
2. High density polyethylene (HDPE)
3. Low density polyethylene (LDPE)
4. Polypropylene (PP)
5. Polystyrene (PS)
6. Other types of plastics

Figure no 1. List of recyclable plastics

METHODS OF EXTRACTING FUEL FROM PLASTIC WASTE

Methods of waste disposal of plastics are as follows;

1. Incineration
2. Pyrolysis- Method of extraction of fuel from plastic waste.

1. Incineration

Incineration is the process of burning the plastic waste upto higher degrees of temperature range at about 700 to 1100 degree Celsius. The burning of the plastics at higher temperature ranges causes the plastics to emit toxic gases like CO, CO_2 and ash. Incineration causes air pollution on greater extent which further causes global warming, which give monsoon failure. There are many drawbacks in incineration process and is costlier.

2. Pyrolysis

Pyrolysis is a process of thermal degradation of the plastics in absence of oxygen. The principle of pyrolysis is as follows:

The plastics are polymers mostly containing of carbon and hydrogen and few other elements like nitrogen, chlorine etc. When the long chain of the polymers breaks at certain points or when lower molecular weight fractions are formed, this is called as degradation of polymers.

There are two methods involved in pyrolysis

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1. Feedstock recycling

Feedstock recycling process is that attempts to recover the original feedback used to manufacture the recycled product, rather than converting the product in another form. It is a form of tertiary recycling and encompasses a number of thermal or chemical processes that recover fuels or raw chemicals from plastic waste.

2. Pyrolysis

Pyrolysis is thermo chemical conversion technology that can be considered as a "feedstock recycling" process and may play an increasing role in integrated waste management systems of the future. The advantage of the pyrolysis is that it can accommodate relatively contaminated feed stocks and value added materials and further they can recovered prior to conversion of fuels

Some of the calorific values of the plastics are given below:

Table no 1. Calorific Value of plastics and fuels

Sr. No.	Materials	Calorific Value
1.	Polyethylene	46,3 MJ/kg
2.	Polypropylene	46,4 MJ/kg
3.	Polystyrene	41,4 MJ/kg
4.	Polyvinyl chloride	18,0 MJ/kg
5.	Coal	24,3 MJ/kg
6.	Petrol	44,0 MJ/kg
7.	Diesel	43,0 Mj/kg

PRINCIPAL OF PYROLYSIS

Pyrolysis is the technique of recycling the plastics which converts the waste into fuels by catalytical cracking process. It allows the treatment of mixed, unwashed plastic waste.

The process of pyrolysis consists for converting plastics to fuel is as follows:

1. Feedstock processing

Depending upon the size of the plant the feedstock is cleaned and crushed. It can be used without cleaning but further it can affect the feed process for continuous system.

2. Feedstock melt/ Extrusion

The shredded or crushed plastic pieces are melted in this stage. The melt cycle also serves excluding of the oxygen from the pyroliser.

3. Load into pyroliser

The loading of the charge is done in pyroliser.

4. Pyrolysis

Plastics are subjected to heat in the absence of oxygen, which depolymerises plastic into gaseous form. Contaminants and other items like fillers are converted into char or carbon black. The temperature for plastic pyrolysis is 370 to 420 degree Celsius and pyrolysis gases are condensed in a two stage condenser to produce low sulphur distillates.

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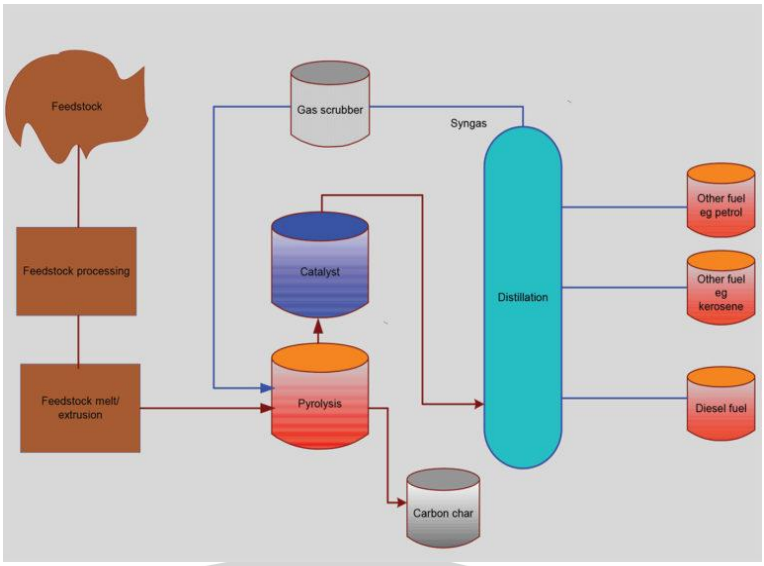

Figure no 2. Block diagram of pyrolysis process.

The generalised process for the pyrolysis is in two steps:

1. Random de-polymerisation

Under various controlled conditions plastics materials undergo random depolymerisation and are converted into three products:

a. Solid Fuel i.e. coke
b. Liquid Fuel i.e. combustion of gasoline, kerosene, diesel, lube oil etc
c. Gaseous fuel i.e. LPG

2. Fractional distillation

In fractional distillation separation of various liquid fuels by virtue of the difference in their boiling points is done. One of the important factor of the quality of the liquid fuel is that the sulphur content is less than 0.002 ppm which is much less than regular fuel.

The various pyrolysis machine consist of following main parts:

1. Reactor

Reactor is a place where the reaction of plastics are taken place. The basic reaction is as given below:

$$C_{15}H_{32} \xrightarrow{\text{zeolite catalyst}} 2C_2H_4 + C_3H_6 + C_8H_{18}$$

2. Catalytic cracker

Catalytic cracking is the breaking of large hydrocarbon molecules into smaller and more useful bits. The cracker must be designed in such a way that the vapour from the reactor must have maximum surface contact with the catalyst. The catalyst will act as molecular sieve which permits the passage of small molecules. The hydrocarbon molecules are broken up in a fairly random way to produce mixtures of smaller hydrocarbons, some of which may have carbon-carbon double bond.

The catalyst used is ZSM-5 Zeolite Socony Mobil-5 is a aluminoslicatezeolite belonging to the pentasil family of zeolites. Its chemical formula is NanAlnSi96-nO192*16 H20 (0<n<27).

3. Condenser

It is the part of the machine which condenses the vapours coming out from catalytical cracker. The condenser must condense the very hot vapours in an efficient manner to give proper condensate. Clogging in the condenser must be prevented. This can be achieved by increasing the diameter of the pipe. Generally spiral condenser is preferred for better results.

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4. Nitrogen cylinder

Nitrogen cylinder is attached to the reactor. It is used to provide inert atmosphere to the reactor. The main purpose to use nitrogen cylinder is to melt the plastic and not to just bum it inside the reactor

Figure no 3. Specimen of recycled plastic fuel.

FUEL CHARACTERISTICS

The fuel characteristics of the recycled pyrolyzed oil are as follows:

1. Viscosity
2. Density
3. Flash point
4. Fire point and Pour point
5. Calorific Value
6. Sulphur and Ash content
7. Carbon Residue

1. Viscosity

Viscosity varies with different parameters such as feedstock, pyrolysis conditions, temperature and other variants. When the viscosity is higher the fuel consumption is also higher and also it increases the load on the engine as well as the temperature of the engine.

In prior case when the viscosity of the oil is too high excessive friction may take place which causes further problem in engine cylinder. The viscosity of the recycled plastic pyrolyzed oil at 430 degree Celsius is about 1.94 cSt which was lower than diesel and higher than kerosene.

2. Density

Density is the important property in the fluid mechanics. If the density of the is high then the fuel consumption rate is less, whereas the oil which has lower density will consume on greater extent. The density of the oil should not be too high or too low it should be in moderate range. The density of pyrolyzed oil is about 0.7944 g/cc which is very close to the density of the kerosene or diesel.

3. Flash point

Flash point is the temperature or lowest temperature at which it is capable of forming vapour which can ignite the mixture in air. Flash point determines the fire hazards of the fuel. The low flash point the fuel indicates the presence of the high volatile nature of the fuel. The flash point of the pyrolyzed fuel is 15 degree Celsius. The flash point of the kerosene is more than the pyrolyzed fuel.

4. Fire point and Pour point

The fire point can be defined as the temperature at which the fuel starts to burn after few seconds of ignition by an open flame. Flash point resembles the ability of fuel to get burn itself or to support combustion. The fire point of the pyrolyzed oil is 20 degree Celsius, generally the conventional fuel has a fire point in range 5-10 degree Celsius respectively.

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The pour point is the temperature at which the fuel ceases to flow or its resistance increases when the fuel is cooled at specified levels. Pour point determines the fuel to get adapted to low temperature applications. The pour point of pyrolyzed fuel is < -15 degree Celsius.

5. Calorific value

The efficiency of the fuel can be determined by the calorific value of the fuel. The calorific value of the fuel is defined as the energy given out when the unit mass of the fuel is burned completely in sufficient air. The calorific value of the pyrolyzed fuel is 9829.35 Kcal/kg.

6. Sulphur and Ash Content

The emission and pollution control norms are the major parameters on which the use of the fuel is been decided. The presence of sulphur in the fuel increases the Sox emissions from the vehicle which can further lead to various environmental issues. The sulphur content of pyrolyzed fuel is 0.246 % which is slightly higher than diesel (0.15%)

7. Carbon residue

Another major parameter in the pollution control norms is carbon residue. Carbon residue indicates the tendency of oil to deposit a carbonaceous solid residue on the hot surface. The carbon residue of the pyrolyzed fuel is about 0.05 % which is comparatively less than diesel respectively.

CONCLUSION

The pyrolysis process leads to the production of the fuel from the plastic wastes. The pyrolysis process utilizes the chemical reaction as its base for the generation of the liquid fuel. Mixed plastic pyrolysis leads to the mixture of the oil and gas with very small amount of char as a byproduct. The stringent use of the plastics and its usage has lead to the recycling of the plastics. Also with the emerging rules and regulations of the Indian Ministry of Road Transport and Highways has lead us to alter the conventional fuel as of the diesel and petrol engines will be altered by the electric cars till 2020. But as the overall power and other parameters are considered for the internal combustion engines, IC engines prove a better performance parameters than electric vehicles. Thus the recycling of the plastics into pyrolyzed fuel is the best option we can opt for making best from waste. As the end to end product serves better performance parameters as compared with conventional fuels respectively.

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