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Design Of Viable Machine To Convert Waste Plastic Into Mixed Oil For Domestic Purpose

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Abstract:- *The aim of this article is to provide a more efficient design of machine to convert waste plastic into mixed oil for domestic purpose. In this machine daily domestic waste like polyethene, polypropylene or normal plastic carrying bag are converted to oil. This machine employs a closed container (stainless steel), temperature controlling electric heater and layers of insulating materials, these materials make machine more efficient and safer for use. For effective pyrolysis process the temperature of stainless steel container (full of waste plastics) is raised by temperature controlling electric heater and for condensation process, water at room temperature is employed. There are three outputs obtained from this machine which are mixed oil, hydrocarbon gas and carbon black charcoal. These products can solve the problem of daily domestic requirement of fuel for local villagers. This machine is only suitable for normal carrying bag of plastic and not for PET bottles or PVC pipes. The design of machine is efficient to manage daily domestic plastic waste and in return provides three types of fuel.*

KEYWORDS:- Domestic waste, Pyrolysis, Mixed oil, Insulating matrials, Cladding

I. INTRODUCTION

Today's world generates millions of tons of plastic waste every month. If we observe current statistics for Western Europe then we find the annual total consumption of plastic products was 98kg/capita for 2003 and the same quantity in 1993 was approximately 64 kg/capita[1]. The demand of plastic is increasing day by day because it plays a crucial role in our daily life, but the accumulation of plastic waste in the environment creates problem for wildlife, fertile land, ocean etc. In 2012, it was estimated that there was approximately 165 million tons of plastic waste in the world's oceans[2]. Humans are also affected by plastic pollution, such as through the disruption of the thyroid hormone axis or hormone levels[3]. The daily used plastics (plastic bag, polyethene, plastic film etc.) are mainly responsible for plastic pollution and these types of plastic are daily domestic waste of local people. It is estimated that 3.36 billion HDPE lightweight carry bags were consumed during 2006[4]. Plastic like PE ,PP,PS etc can be converted into oil by the help of thermal depolymerisation process . This thermal depolymerisation process in an inert atmosphere is called pyrolysis. Plastics are typically made from petroleum and the design of this machine is capable to reconvert or recycle these plastics into mixed oil (petroleum). This mixed oil is capable to fulfill the daily demand of fuel of local villager's of India and can reduce the scarcity of fuel for domestic purpose. It is estimated that 7% of the world's annual oil production is used to produce and manufacture plastic. That is more than the oil consumed by the entire African continent[5]. The design of this machine is made for domestic purpose, it is small, safe and easy to use. "This plastic waste is everywhere in India, and everyone throws it away'' , but after the introduction of this machine people will think 10 times before throwing the plastic and if they are still throwing this plastic then indirectly they are throwing a packet of oil not plastic.

II. PYROLYSIS

It is the process of conversion of plastic to mixed oil in an inert atmosphere or oxygen free atmosphere at elevated temperature. It is used to produce liquid fuel similar to diesel with a higher cetane value and lower sulphur content than traditional diesel[6].

a. PHYSICAL PROCESS INVOLVED

Performing pyrolysis process the plastic starts melting and after melting process gaseous phase occurs. The mixture of gases formed are again converted into liquid by condensation process. After the condensation process, layer of oil is appeared above water.

b. CHEMICAL PROCESS INVOLVED

Conversion of plastic into fuel involves thermal depolymerisation or catalytic thermal depolymerisation process. By increasing temperature the vibration amplitude of plastic's molecules increases and at an optimum temperature bond of plastic molecule is cleaved and converted into gaseous form. The above process can also be referred as Random thermal depolymerisation process, because the bond is breaking randomly.

2.2.1 THERMAL DEPOLYMERISATION PROCESS

In this process only high temperature pyrolysis is employed in order to increase entropy (randomness) of plastic molecules. The Pyrolysis Oil obtained from this process is crude oil having major quantity of heavy oil .According to the Japanese Blest company temperature range between 400 to 450 degree Celsius is suitable for the production of lighter mixed oil in which diesel and heavy oil etc are major constituents[7,8]. But by increasing temperature beyond 500 degree Celsius heavy oil constituent increases and quantity of oil decreases. However quantity of gaseous components increases due to the formation of non condensable gases of small chain length. But this gas is equivalent to the LPG (may require refining).

Above mentioned temperature is suitable for PE, PP and PS and not for PET bottles and PVC pipes. Through this process mixed oil is obtained which needs refining process for better output. According to the Japanese blest company the oil is obtained after refining process has following composition[8].

Averagely,

Kerosene equivalent: 20-30%

Gasoline equivalent: 15-20%

Diesel oil equivalent: 20-30%

Heavy oil equivalent: Remains.

But above composition also depends upon the composition of plastic used.

2.2.2 CATALYTIC THERMAL DEPOLYMERISATION PROCESS

When the thermal depolymerisation process is performed in presence of a catalyst then it is called catalytic thermal depolymerisation process. Catalyst plays an important role in pyrolysis process. It increases both quantity and quality of oil. In presence of HZSM-5 zeolite catalyst, plastic waste was converted to lighter fractions at 425 °C, even at lower reaction time 30 min. It improved oil and gas yields while char yield reduced. It increased the yield of alkanes by increasing propane gas ratio to nearly 50 % gas yield as well as butane yield while other gases yield reduced such as alkenes, hydrogen and carbon mono oxide (Table 1)[9].

Table 1.Yield of pyrolysis products.

product yield, wt %	Thermal Pyrolysis (No catalyst)	Catalytic Pyrolysis with Zeolite
Oil	76.7 ±1.2	81.4 ±0.96
Gas	7.3 ±0.50	9.6 ±0.81
Solid Residual	16 ±1.2	9±0.4

But the major problem of catalyst is its cost. Catalyst takes 64 percentage of production cost[10]. So it is only economical for large scale industry not for domestic purpose.

III. DESIGN OF MACHINE FOR DAILY DOMESTIC PURPOSE.

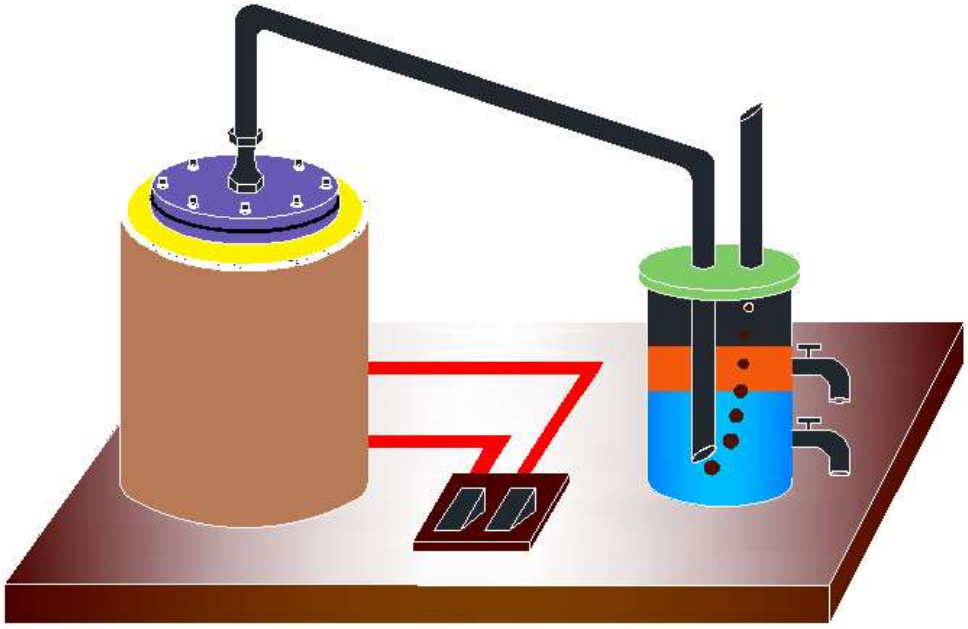

Fig.1. This is design (CAD) of machine for daily domestic purpose.

Waste plastic is raw material for this machine (Fig.1.), it converts waste plastic into mixture of gases by providing heat from electric heater in a closed container. These gases are again converted into crude oil by condensation process with the help of water at room temperature and the non condensable gases can be collected into another chamber for further uses. The pyrolysis oil can be recovered from machine by opening upper tap. Design of this machine is also suitable for catalytic thermal depolymerisation process.

IV. SPECIFICATION OF EACH PART OF THIS MACHINE

4.1 FURNACE PART

TEMPERATURE CONTROLLING ELECTRIC HEATER - This electric heater is employed for maintaining the temperature between 400 to 450 degree Celsius of the furnace. It is also one of the safety measures in order to prevent overheating of the container. Electric heater is fitted at the bottom of furnace in order to provide maximum heating effect to the bottom surface area of closed container (as in Fig.2.).

Fig.2. Top view of furnace (demonstrative prototype model).

INSULATING MATERIALS- In order to provide insulation two different insulating layers are employed.

Fig.3. Side view of furnace (demonstrative prototype model).

a) **REFRACTORY MATERIAL**: A thick layer of refractory material is used to insulate the apparatus and also provide better resistance to thermal shock. According to the thermal conduction process of heat,

$$\text{Heat current} = \frac{\text{Temperature difference}}{\text{heating resistance}}$$

So heating resistance for above cross section (fig 2):

$$R = \int_{r}^{r+t} \frac{dx}{2\pi \text{kxH}}$$

$$R = \frac{\log\left[1+\frac{t}{r}\right]}{2\pi kH}$$

$$\text{Heat current} = \frac{2\pi \text{kH}(\text{T}-\text{T}_0)}{\log\left[1+\frac{t}{r}\right]}$$

Where R = Heating resistance.
r = Inner radius of furnace.
t = Thickness of refractory material.
K = conductivity.
H = Height of furnace.
T = Temperature of furnace.
T_0 = Temperature of atmosphere.

So by increasing the thickness of refractory material heat current decreases and also reduces heat loss. But this parameter also depends upon the weight of the machine.

b) **GLASS WOOL**: Glass wool is an insulating material made from fiber of glass arranged using a binder into a texture similar to wool (fig.2.). The coating of glass wool traps many small pockets of air between the glass, and these small air pockets result in the thermal insulation properties[11].

4.2CLOSED CONTAINER PART

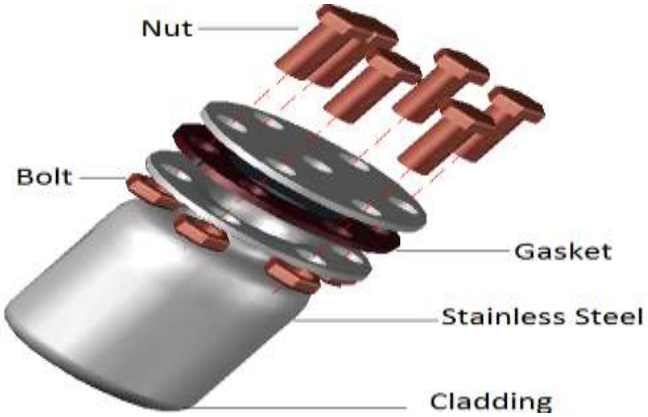

Fig.4. Exploded view of closed container (stainless steel) and other parts.

STAINLESS STEEL CONTAINER- Pyrolysis process is performed in this container at high temperature (400 to 450 degree Celsius). Stainless steel container is favourable for this range of temperature because it has high melting point and resisting property against oxidation. The bottom surface area of this container is large to provide a good surface area for the conversion process (fig.4.). Thickness of this container is in range of 2 to 4 mm which depends upon the capacity of machine to convert plastic.

GASKET- Gasket is used to provide mechanical seal and it also fills the space between two surfaces.

CLADDING - Thermal conductivity of stainless steel is not high so in order to maintain the effect of heat uniformly over the bottom surface area of container cladding process is to be done. Here bottom surface of stainless steel container is cladded with copper or aluminium (fig.4.).

K TYPE THERMOCOUPLE- It is employed to measure the temperature of closed container.

V. KINDS OF PLASTIC USED IN THIS MACHINE

Polyethylene (HDPE, LDPE, LLDPE), polypropylene and polystyrene are the types of plastic which can be converted into oil, whereas PVC and PET bottles are non convertible by this machine because both require temperature more than 500 degree Celsius and PVC cracking is not preferable in the fuel product because chloride is not desirable in the fuels.[12]

VI. OUTPUT PRODUCTS OF MACHINE

The output products of this machine are pyrolysis oil, hydrocarbon gas and carbon black charcoal.

Fig.4. Carbon black charcoal and pyrolysis oil extracted as a output of machine.

Hydrocarbon gas is very less emitted, after condensation it can also be used for daily domestic purpose. Obtained oil can be used in stove, generator or other daily domestic purpose, but for commercial purpose obtained oil needs refining and after refining process this oil is equivalent to diesel and petrol. Table no 2 shows physical properties of petrol and diesel obtained after the distillation of mixed oil or pyrolysis oil[14].

Table no 2. Physical properties of petrol and diesel grade of waste plastic.

S.NO	Characteristics	Petrol grade fuel	Diesel grade fuel
1	Flash point (degree Celsius)	29	87
2	Fire point (degree Celsius)	33	92
3	Viscosity	.8	3.8
4	Density kg/m3	.735	.800
5	Calorific value kj/kg	47817	46988

VII. SUMMARY

This article is centralized on the idea that plastic is convertible into mixed oil. The design of the machine is efficient in this conversion. The unique feature of the design is that it is made for small scale or domestic purpose and is convenient with respect to size and weight (so that it is easily portable). In the machine pyrolysis process takes place in a temperature controlled heater which is very essential for the efficient output of oil. Layers of Insulating material prevent undesired heat loss and also provide better safety to the user. The only drawback of this machine is that the waste plastic used in the process should be in non complex form (i.e. not mixed with other type of waste like food materials etc). This drawback can be improved through proper waste management and categorical waste deposition. Oil obtained in the process can be used in stove, generator, boiler's fuel or other daily domestic purpose etc. This machine will help in waste management and will reduce domestic waste and in return will provide a fuel for different domestic purposes. Polythene and other plastic products are mainly responsible for soil erosion and other environmental problems and by using this machine these activities can be reduced to a greater extent. This machine can be used by local rag pickers to produce oil and contribute to waste management at places where municipal system is not available or not working efficiently. This design of the machine would contribute a lot to the development of the waste management system in the country.

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