Extraction of Pyrolytic Fuel from Non-biodegradable Solid Wastes

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Abstract- Leather and Styrofoam are very common figures in our day to day life, as a result a large amount of worn leather and used Styrofoam are thrown away as wastes. These wastes take a long time to biodegrade. So these play a vital role in environmental pollution. But if these wastes are further processed by pyrolysis, valuable energy such as pyrolytic oil, char and gas can be obtained which can meet the crisis of energy. In this project a simple pyrolysis system is introduced with a fixed bed reactor, two condensers, and two outlet pipes, in which the waste leather and Styrofoam are processed to obtain fuels. The shredded leathers and Styrofoam are fed into the reactor and heated up to a fixed temperature. The condensation process is carried out during the passage of the gas (volatile material) formed due to heating the shredded wastes to form pyrolytic fuel. Further different properties of the fuel such as density, viscosity, Calorific Value, boiling point and flash point are determined and a comparison between leather and Styrofoam with diesel and gasoline were made. From the observations it has noticed that, the properties of the pyrolytic oils obtained from leather and Styrofoam don't fully match with the properties of diesel and gasoline. The Styrofoam can be used as a fuel by further processing but the oil from leather cannot be used as a fuel but can be used as lubricant in the engine.

Index Terms— Non biodegradable solid waste (NBDSW), Pyrolysis, Leather, Styrofoam, Fixed bed, Char.

INTRODUCTION

The energy crisis and environmental degradation are the main problems mankind is facing today. These problems owe their origin to a growing population, rapid industrialization and huge quantities of non biodegradable solid wastes (NBSW), which are generated daily. NBSW are those which biodegrades slowly, such as plastics, leather, styrofoams, tire etc. Every year a huge amount of waste leather and Styrofoam cups, plates are disposed in the environment. From an appendix worldwide an estimated 60 billion kilo of leather is lost (burning, landfill etc.) every year [1]. The estimation of leather wastes in world basis is given bellow.

TABLE-1 ESTIMATION OF THE WASTES GENERATED BY LEATHER MANUFACTURING - WORLDWIDE BASIS

Countries	Leather wastes (tons/year)
China	105198
Asia	195319
Middle east	37521
Eastern Europe	18264
Western Europe	186834
South America	87225
North and central America	60018

Rest of the world	115277
total	805606

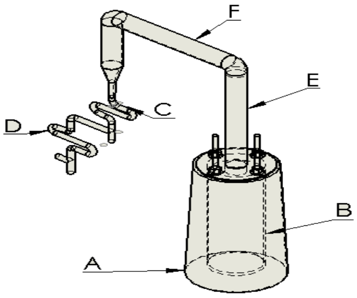
On the other hand, Styrofoam is mostly uneconomical to recycle or otherwise to process. As waste material, it exists in massive quantities, is environmentally useless and can be lethal to any bird or sea creature that swallows significant amounts. Weight based the volume of Styrofoam is approximately 50 times that of municipal solid waste. U.S. Environmental Protection Agency (EPA) states: each year Americans throw away 25,000,000,000 Styrofoam cups. Even 500 years from now, the foam coffee cup one used this morning will be sitting in a landfill [2].So if the worn leather and Styrofoam can be converted into useful energy sources by appropriate technologies, the energy crisis as well as the environment pollution will be sorted to some manner. Thermal conversion involves the use of a wide range of thermal decomposition processes Such as pyrolysis and gasification to decompose waste materials into smaller molecules that can be used as energy source or inputs for the synthesis of new materials, e.g. Hydrocarbon wastes are decomposed to produce syngas (H_2+CO); the syngas can be used as a fuel directly. [3] In pyrolysis process waste materials are heated and cracked in the absence of oxygen into smaller molecules. While thermal conversion shows advantages in dealing with a wide variety of wastes of a hydrocarbon nature (e.g. used tires [4] and plastic wastes [5]), and recovering both the energy and chemical value of the wastes [6]. Although thermal conversion techniques have recently shown potential as an environmentally friendly waste disposal method [7], such practice is yet to become popular.

PYROLYSIS

Pyrolysis liquefaction is a non-combustion heat treatment that catalytically (chemically) decomposes waste material by applying heat, directly or indirectly to the waste material in an oxygen free environment. It is an endothermic reaction which requires an input of energy that is typically applied indirectly through the walls of the reactor in which the waste material is fed into. Pyrolysis liquefaction occurs under pressure and at operating temperature of about 400ºc to 900ºc The basic phenomena that take place during pyrolysis are [8]:

- Heat transfer from a heat source, leading to an increase in temperature inside the fuel
- Initiation of pyrolysis reactions due to this increased temperature, leading to the release of volatiles and the formation of char;
- Out flow of volatiles, resulting in heat transfer between the hot volatiles and cooler unpyrolysed fuel;
- Condensation of some of the volatiles in the cooler parts of the fuel to produce tar
- Auto- catalytic secondary pyrolysis reactions due to these interactions.

Fig. 1 shows the simple pyrolysis system where leather and Styrofoam can be pyrolysed easily, and the volatile material easily condensed in the condenser



Here,
A: Outer Cylinder
B: Inner Cylinder
C and **D**: Condensers
E and **F**: Outlet Pipes

Figure 1.0 Simple pyrolysis system

Pyrolysis oil is a complex mixture of chemicals resulting from the thermal decomposition of biomass. The types and amounts of each chemical may vary widely depending on the thermal process used. Pyrolysis oil is also known as bio-crude, bio-oil or bio-leum. [9]. Typical industrial applications of pyrolysis oil as a fuel is in boilers, furnaces, hot water generators, hot air generators, thermal fluid heater, electric generators, diesel pumps etc. The gas product is termed synthesis gas, shortened to syngas. It is generally composed of carbon dioxide, carbon monoxide, methane, hydrogen and two-carbon hydrocarbons in varying proportions. In this report it is often referred to as the gas product and generally re-used in plant [10-11].Char is the solid material that remains after light gases (e.g. coal gas) and tar have been driven out or released from a carbonaceous material during the initial stage of combustion i.e. Pyrolysis [12]. Generally char is used in rubber industry, plastic industry, paints, inks etc. Figure 2.0 shows the as prepared pyrolysis system.

Figure 2.0 As prepared pyrolysis system

EXPERIMENTAL

3.1 Pyrolysis of Leather

In leather pyrolysis process worn leathers were collected from different places and after removing dust they were shredded into small rectangular pieces of about 0.5 inch. Those shredded leathers were placed into the reactor and then the system was ready for the pyrolysis process. The total system was placed on the kerosene stove and heat was supplied to the reactor. For a fixed feed volume of 250 gm of shredded leather, the experiment was carried out up to a temperature of about 800 ºc. In each experiment the flaring of the white vapor from the condenser pipe started at a temperature of about 250ºc. So the volatile material began to form at this temperature. At a certain fixed temperature the white vapor with high volatile content was passed through the condensers and get condensed into liquid oil in the collector by means of gravitational force. The uncondensed gases were passed through the condenser flared to the atmosphere. But as the temperature increased from 450ºc to 600ºc, the precedence time of the condensed oil decreased i.e. as the temperature increases the more pyrolytic oil from leather condensed can be obtained within a decreasing time. At a temperature of about 700 ºc the white vapor stopped to flare. The heating process was carried out for an hour or more. The absence of white vapor indicates that the reaction was over and the worn leather totally converted into pyrolytic oil, char and gas. So the stove was turned off and the oil from the collector was collected in the beaker and weighed. After cooling down the system the char from the reactor was collected and then weighed. The weight of the gas flared to the atmosphere was found by subtracting the weight of the char and oil from the total weight of the worn leather.

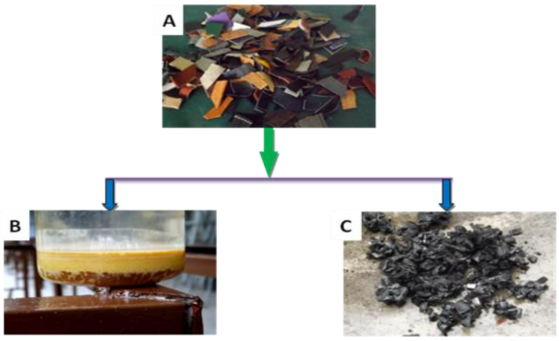


Figure 3.0 Pyrolysis of leather; (A) shredded leather wastes, (B) pyrolytic oil from leather, (C) char

3.2 Pyrolysis of Styrofoam

At first the used plates, cups etc of Styrofoam were collected from different places and then after removing dust shredded them into small pieces of about 0.25 inch. The shredded Styrofoam of about 50 gm then placed into the rector and the reactor placed on the stove. The reactor temperature was increased up to 500ºc. About 10 minutes the Styrofoam started to melt down. The Temperature of the reactor was measured with a temperature recorder to be 250 ºc. After about 15 minutes the Styrofoam started to evaporate when the temperature of the reactor was at 330 ºc. Five minutes later the reactor temperature was 360 ºc and the first drop of condensed vapor was collected at 60 ºc. The temperature of the condensed vapor increased quickly from 60ºc to 131 ºc. The pyrolysis system continued for 80 minutes and stopped when the temperature of the condensing vapor dropped to 70 ºc while the reactor temperature was above 450ºc. Thus the liquid obtained from pyrolysis process was 37 gm, which was a 70% yield to liquid. The volatile material that was not condensing by a water cooling condenser at room pressure was not collected. The leftover was 8 gm of a high viscous dark material in the bottom of the reactor. So the amount of volatile material that was not condensed was 6 gm.

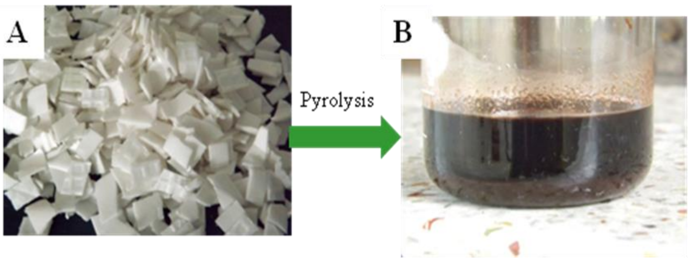


Figure 4.0 Pyrolysis of Styrofoam waste; (a) Shredded Styrofoam plates, (b) pyrolytic oil from Styrofoam

RESULTS AND DISCUSSION

Table 2.0 shows the different product produced during the pyrolysis of leather:

TABLE 2.0 PRODUCT OF PYROLYSIS OF LEATHER

The amount of liquid, solid and uncondensed vapor produced during pyrolytic conversion of waste Styrofoam is shown in table 3.0.

Observation no	Product yield Liquid (oil) (gm)	Solid (char) (gm)	Gas (gm)	Residence time (min)
01	203	29	18	83
02	195	32	23	80
03	216	22	12	73
04	207	31	12	78

TABLE 3.0 PRODUCT OF PYROLYSIS OF STYROFOAM

Observation no	Liqud (oil) (gm)	Product yield Solid (char) (gm)	Gas (gm)	Residence time (min)
01	42	3	5	55
02	45	2	3	62
03	39	5	6	57
04	42	2	6	66

TABLE 4.0 PHYSICAL PROPERTIES OF PYROLYTIC OIL DERIVED FROM LEATHER & STYROFOAM

	Extracted Oil		Diesel	Gasoline
	Leather	Styrofoam		
Density (ρ)	1010.6	854	820-850	719-780
Kinematic Viscosity (cSt)	1.69	4.63	2- 4.5	1.95-3.3
Gross Calorific value (MJ/kg)	28.63	39.38	44-46	43.2
Boiling point (°C)	102	148	180-360	100-400
Flash point (°C)	36	52	53- 80	N/A

Different properties of pyrolytic oil extracted from leather and Styrofoam like Kinematic viscosity, Gross calorific value, boiling point, flash point etc were determined in the laboratory. The oil produced from the leather was brown in colour with an acidic smell. It reacts with skin and acrid smell for a few days. It stored in an air tight bottle but its colour or physical properties didn't change. The oil produced from the Styrofoam was less dense than the oil from leather. It also posses acidic odor and react with human skin.

CONCLUSION

Leather and Styrofoam is an important new alternative transportation fuel. It can be produced from any kind of waste leather and Styrofoam. This technique has extended to allow pyrolytic fuel production from different non bio degradable solid wastes. Adherence to a quality standard is essential for proper performance of the fuel in the engine and will be necessary for widespread use of these fuels, obtained from leather and Styrofoam. But between these two the fuel from Styrofoam is better than the fuel from leather. Because it possesses good calorific value which ranges between the diesel and its other properties are near to the properties of diesel and gasoline.

This report investigates parameters of pyrolytic fuel from leather and Styrofoam. The results of this work can be summarized as follows:

- The production of the pyrolytic fuel from non biodegradable solid wastes (leather & Styrofoam) was done by heating them in inert atmosphere in a fixed bed reactor and condensing them in an optimum temperature.
- The optimum temperature for extracting oil from pyrolysis process was observed 600°C for leather and 250°C for Styrofoam.
- The optimum reaction time was observed to be 40 min for leather and 25 min for Styrofoam.
- The fuel properties of leather and styrofoam is determined and shown in this report
- From the comparison of fuel properties between leather and Styrofoam, Styrofoam showed better properties than leather.
- There are some impurities in the produced pyrolytic oil. so if refinement is done then the properties of the oil can be changed and can make these oils more valuable and more suitable.

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