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Generation of Electricity Using Fuel Oil From Municipal Plastic Waste

[1] R. Rashi, [2] Akhila.S.Raj, [3] Danish Jose S R, [4]Sujatha S, [5]Prasanth , [6] K. Somanandan, [7]Dr.V.V. Karunakaran
[1] [2] [3] [4] Student,EEE, Sarabhai Institute Of Science And Technology(SIST)
[5] Associate Professor, EEE, SIST
[6]HOD,EEE, SIST
[7]Former Principal,SIST.

Abstract: ***Effective management of plastic wastes has been a long-standing problem faced by modern societies and a lack of proper management of waste plastic has resulted in a huge menace to mankind. In this work, plastic waste from municipality was sorted and subjected to pyrolysis in the presence of bentonite and silica, at a temperature of 330 °C, using a custom-designed pyrolysis and condenser unit. The emergent vapor from the pyrolysis unit, after passing through the condenser was collected to get the fuel oil, which was characterized using Fourier transform infrared spectroscopy. 1.5 l of fuel oil was obtained using 3 kg of sorted plastic waste. Performance of the obtained fuel oil as an alternative fuel was demonstrated by producing electricity using a diesel AC Generator of 7.5 KVA, using a fuel mixture containing 25% of obtained fuel oil and 75% commercial diesel, loaded for 0.5 h.***

I. INTRODUCTION

Plastics are made of polymers, which are long chains of organic molecules, and were invented in 1860. The polymers are usually made into granules, powders and liquids, which become raw materials for plastic products. Due to their light weight, durability, energy efficiency, coupled with faster rate of production and design flexibility, plastics are employed in entire gamut of industrial and domestic applications. Plastics are primarily produced from petroleum derivatives and are composed primarily of hydrocarbons but also contain additives such as antioxidants, colorants and other stabilizers. Plastics are non-biodegradable polymers mostly containing carbon, hydrogen, and few other elements such as nitrogen. Due to its non-biodegradable nature, plastic waste contributes significantly to the problem of waste management. Disposal of the waste plastics poses a great hazard to the environment and effective methods have not been implemented to address the hazards. According to the ministry of environment, forest and climate change of the Government of India, approximately 15,000 tons of plastic waste were generated in India every day, as of 2016, of which 6000 tons remain littered and uncollected. Hence, effective interventions are required to address the challenge.

The per capita consumption of plastics in India is about 3 kg when compared to around 40 kg in the developed countries. Most of these come from packaging and food industries. While most of the plastic wastes are recycled in developed countries, the lack of sufficient market value hinders such efforts in India. The approach currently being followed in India relies primarily on source reduction, reuse and recycling, and much less on recovery of the inherent energy value through waste-to-energy incineration and processed fuel applications [3]. Interestingly, about 43% of plastic wastes, mostly from containers and packaging, contain polyethylene which has a high calorific value (40 MJ/kg) comparable to that of fuels [3]. Hence it is imperative that production of liquid fuel is pursued to not only generate alternative energy, but also for a better mitigation of the menace of plastic wastes. Plastics recycling is currently being done using a wide range of old and new technologies [4] and chemical recycling of waste plastics to fuel and monomer has also attracted significant interest. A number of pilot, demonstration, and commercial plants processing various types of plastic wastes have been successfully completed in Germany, Japan, USA, India, and elsewhere.

In this work, we report the production of electricity using liquid fuel oil obtained from the pyrolysis of sorted municipal plastic waste in the presence of bentonite and silica as catalysts, using a custom-designed pyrolysis and condenser setup. Details of the fabricated setup and characterization of the liquid fuel obtained are also presented.

II. EXPERIMENTAL

The heart of the experimental apparatus was a vertical tubular pyrolysis reactor. The reactor was fabricated using mild steel plates of 3 mm thickness, by using arc and gas welding. The photograph of the fabricated pyrolysis unit is shown in the Fig.1.

Fig.1 Photograph of the pyrolysis and condenser unit

A feeder was attached to the reactor‘s upper end which enabled pre-determined amounts of plastic waste to be added before operation. Before start of the pyrolysis process, an optimum amount of 3 kg of sorted polythene waste together with 30 g each of bentonite and silica powders were fed to the pyrolysis reactor and sealed. Charcoal and Waste Wood were used as the fuels of combustion for heating the pyrolysis chamber. A type K (Chromel-Alumel) thermocouple with a digital read-out was used to monitor the temperature of pyrolysis, as a function of time. The thermocouple was inserted into a thermowell pipe welded at the top of the reactor, with the bottom of the pipe at a height of 10 cm from the base of the reactor, such that the thermocouple accurately measures the temperature of the liquid formed inside the reactor during the pyrolysis process. A diagram representing the entire setup is shown in Fig. 2. The condenser unit was made of straight galvanized-iron pipes and running tap water at 30 °C was used to cool the emergent vapor.

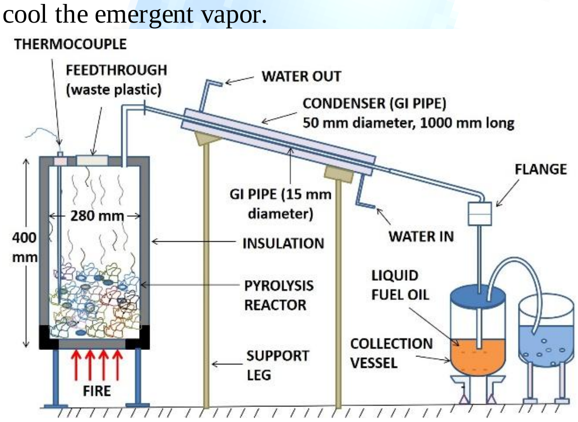

Fig.2 Schematic of the designed experimental setup for pyrolysis process

The temperature of the reactor was raised to 160 °C, at a heating rate of 3 °C/minute and kept at the same temperature for 30 minutes, in order to remove any trapped water vapor that may be present in the plastic waste. The temperature of the reactor is subsequently raised to 330 °C, and the pyrolysis process was allowed to continue for 2 h. The liquefied fuel was collected using a sealed vessel, with provision for gas outlet. The residual gas outlet from the sealed vessel was subsequently passed through a water bubbler, in order to minimize the impact of the gases on the environment.The weight of the reactor before feeding the plastic waste, the weight of the plastic waste, the weight of the collected liquid fuel oil and the weight of the reactor after the pyrolysis process were all accurately measured using a weighing balance.

The collected liquid fuel oil was purified by filtering out any wax or solid components that may be present, by using a filter paper.

Fourier transform infrared (FTIR) spectroscopy was carried out on the purified fuel oil using a Shimadzu DRS 8000A spectrometer (Shimadzu Corporation, Japan), wherein the liquid sample was loaded in a sealed quartz cell . Measurements were done in the transmission mode in the range 400–4000 cm^{-1}. In order to evaluate the ability of the obtained fuel oil in generating electricity, the

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fuel oil was mixed with commercial diesel in the ratio 1:1 and was used as fuel to generate electricity using a 5KW AC generator (Denki, Kirloskar, India).

III. RESULTS AND DISCUSSION

During the pyrolysis of the sorted polythene plastic waste, liquid fuel oil started to get collected when the temperature of the reactor exceeded 240 °C. Pyrolysis is a thermochemical decompositon of organic material at elevated temperatures in the absence of oxygen. It involves a simultaneous chemical decomposition and change in physical phase, and hence is irreversible. Pyrolysis differs from other high-temperature processes like combustion and hydrolysis in that it usually does not involve reactions with oxygen, water, or any other reagents. In practice, it is not possible to achieve a completely oxygen-free atmosphere. Since some oxygen is invariably present in any pyrolysis system, a small amount of oxidation does occur. Hence, it was important to characterize the collected fuel oil to verify its constituents. As seen in Fig. 3, the collected liquid fuel oil was non-transparent and had a deep brown color.

Fig.3 Photograph collected liquid fuel oil.

The FTIR spectra obtained for the fuel oil is shown in Fig. 4. Analysis of FTIR spectra, reveals the presence of a variety of functional groups.

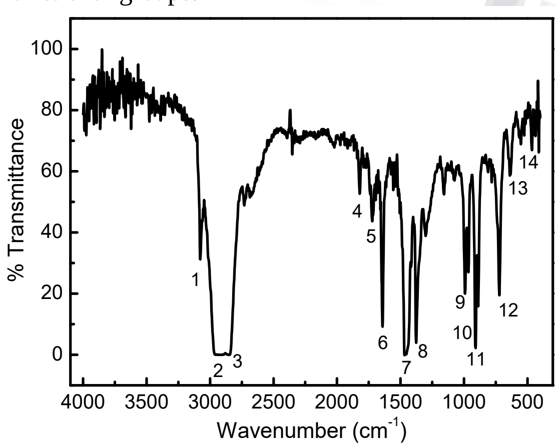

Fig. 4 FTIR spectra of the liquid fuel oil. The identified peaks are labelled.

The details of the FTIR spectra analysis is shown in Table I. The functional groups present in the fuel oil are identified as H-bonded NH, C-CH_3,CH_2, CH_3, -CH=CH_2, -CH=CH-(Cis) and –CH=CH-(Trans). Besides these, a fraction of carbon remains non-conjugated. The presence of the functional groups confirm that the obtained liquid is indeed an organic fuel and can be used as an alternative fuel.

TABLE I. List of functional groups identified in the FTIR analysis of the liquid fuel oil.

Number of the peak	Wavenumber (cm^{-1})	Functional Group
1	3074.5	H-bonded NH
2	2929.8	C-CH_3
3	2854.0	CH_2
4	1822.3	Non-conjugated
5	1720.1	Non-conjugated
6	1641.4	Non-conjugated
7	1463.9	CH_3
8	1375.2	CH_3
9	991.4	-CH=CH_2
10	964.4	–CH=CH-(Trans)
11	908.5	-CH=CH_2
12	721.3	-CH=CH-(Cis)
13	638.7	Non-conjugated
14	410.8	Non-conjugated

The results presented in Table I are comparable with that published elsewhere, for fuel oil obtained using a similar methodology [5]. Hence, the fuel oil was used to run a diesel ac generator. One liter of a fuel mixture of 25% of the obtained fuel and 75% of commercial diesel was used to generate electricity of 230 V and 32.6 A, for 0.5 h. The results suggest that the obtained fuel can be used as an alternative fuel.

IV. CONCLUSION

A pyrolysis reactor and condenser unit was successfully fabricated for conversion of sorted municipal plastic waste into a liquid fuel oil of high calorific value. Pyrolysis of a feedstock of 3 kg of polythene waste in the presence of 3% catalysts yielded 1.5 l of liquid fuel oil and 1.55 kg of bitumen. FTIR analysis of the obtained fuel oil revealed that the fuel oil has high hydrocarbon content and can be used as an alternative fuel. Performance of the fuel oil was demonstrated by generating electricity using the oil mixed with commercial diesel in the ratio 1:3 in a commercial diesel ac generator. The results suggest that pyrolysis of plastic wastes can be taken up by municipal bodies to mitigate the menace of plastic waste, with the added advantage of obtaining a fuel oil which can be used for generating electricity.

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