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An Assessment of Fuel from Disposed Plastic Containers for Diesel Engine

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Abstract

The present work is focused on the methodology for production of alternative fuel for automobile engines along with waste material management. This is done using pyralysis, which is a technique used to produce liquid fuel from solid waste material using a reactor unit. In the present investigation, an electrically operated pyrolysis reactor unit with thermostat (a temperature control device) with water-cooled condenser is used for the pyrolysis process. An attempt is made to obtain the pyrolysis oil from the waste plastic bottles disposed of after use. Used plastic bottles are collected from various places like railway station, restaurants and other places where disposable water bottles and other plastic containers are thrown away. These plastic bottles and containers are initially washed for removing impurities and then dried in the open air for about two days. In the experimental process, 2.5 kg of crushed bottles are taken and using pyrolysis reactor unit these are converted into oil. Brown colored oil produces after the process is collected. Various ignition properties of the pyrolysis oil obtained are evaluated and analyzed. Important characteristics of the fuel obtained from the pyrolysis process are compared with the high-speed diesel. It is observed that the obtained pyrolysis oil has properties similar to the high-speed diesel. Experimental investigation reveal that ignition properties of the pyrolysis oil are suitable for use in diesels engine with minor design modifications.

Keywords: Pyrolysis oil, alternative fuels, dissipated containers, fuel properties

1. Introduction

The demand of the petroleum product is increasing day by day. The natural resources of petroleum fuel are limited and going on depleting very fast. So, it's need of the hour to find the new alternates of these fuels. These finite resources of petroleum are highly concentrated in certain regions of the world have given rise to uncertainty in its supply and price and are impacting growing economies of countries like India, where imports approximately 80% of the total demand for crude. Table1 clearly indicates that India's petroleum product consumption has increased from 1×10^9 tons in 2001-02 to 1.3×10^9 t in 2008-09 at a CAGR of 4.1% and is likely to increase up to 2.2×10^9 t by 2020- 21 and 3.3×10^9 t by 2030-31, resulting in the steep rise of under-recoveries of oil marketing companies at different levels of crude prices. This makes it difficult for the government to subsidize petroleum products in the future. Around the world, there are initiatives to replace gasoline and

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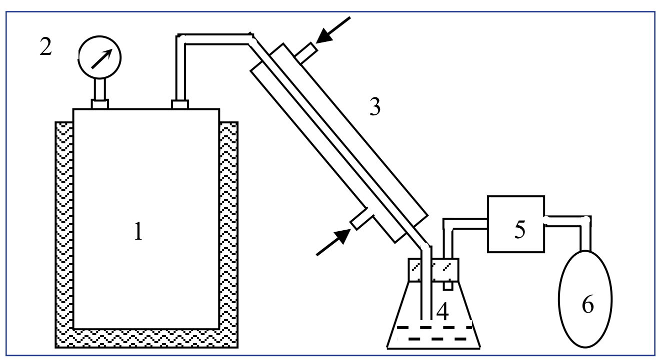
diesel fuel due to the impact of fossil fuel crisis and hike in oil price. Millions of dollars are being invested in the search for alternative fuels. On the other hand, the disposal of plastic from various packagings like water containers is becoming more and more complex (Kaminsky and Menzel, 2012). The development of alternative-fuel technologies are investigated to deliver the replacement of fossil fuel. The focused technologies are bio-ethanol, bio-diesel lipid-derived biofuel, dissipated oil recycling, pyrolysis, gasification, dimethyl ether, and biogas. To convert waste material into fuel is an effective way of waste management, that creates a research scenario is in this field since last two decayed. Many researchers are focusing on the conversion of waste into fuel. In the earlier period Scott et al., 1985 Liquid products (Bio-fuel) was developed from pyrolysis of wood and cellulose in the initial stage. Further Adjaye and Bakhshi(1995) work on catalytic upgrading of a bio-oil obtains from fast pyrolysis of biomass. Agrawal (1988) describes pyrolysis of cellulose by three-reaction model. Tsai et al. (2006) work on pyrolysis of rice straw, sugarcane bagasse and coconut shell in an induction-heating reaction. Zheng et al. (2007) produce Bio-oil from the cotton stalk. Marsman et al. (2007) worked for Identification of components in fast pyrolysis oil and upgraded products by comprehensive two-dimensional gas chromatography and flame ionization detection. Pyrolysis of Bangladeshi was done by Islam et al. (2008) for the production of liquids fuels and chemicals. Vispute and Huber (2009) work on wooden derived pyrolysis oil. Pine trees waste was used for the study of decomposition characteristic by Kim et al. (2010). Heo et al. (2010) work on Fast pyrolysis of rice husks under different reaction conditions. Cunha et al. (2011) attempt on the low-temperature conversion of waste biomass (sugarcane bagasse) to bio-oil to liquids and study effect of combined hydrolysis. Guo et al. (2011) reported similar work with rice husk. On the other hand, appropriate waste management strategy is another important aspect of sustainable development since the waste problem is concerned in every city (Rutz and Janssen, 2007). In the current scenario, the researchers are focusing on waste management. Panda et al., 2010, Sarker et al., 2011, Sharma and Murugan 2013 Vardon et al., 2013, Sharma et al., 2014, Pham et al., 2015, Shi et al., 2016 and Bulukumar et al., 2018 etc. work on alternate fuel along with waste management. India ranks seventh in the production and eighth largest end user in plastic packaging. Indian food packaging Industry plays a very vital role in the Indian national economy. It is estimated that 3.5 MMT of plastic containers are scraped globally from which 28% comes from the emerging market likes India, Southeast Asia, China, India, South America, South Africa, and Eastern Europe. In India, million tons of scrap containers are available annually. This figure is increasing at a very high rate as the number of vehicles is increasing in various sectors and abuts to reach the Western level. It has become a major issue to dispose of the waste containers which has become a major environmental concern globally. The main reason for this is that increasing use of the packaging as well as population, especially in the industrialized nations. The main reason for the problem caused by dissipated packaging is that it is not biodegradable and if there is no proper management it will remain in the same state for several decades (Wankhade and Bhattacharya, 2007), Now a day's using these dissipated plastic containers pyrolysis oil is produced by many companies using pyrolysis process. The produced oil has some properties in resemblance to diesel oil.

2. Materials and Methods

Pyrolysis oil from crushed plastic bottles was derived in 2018 during the project work in institution. In the present work, from crushing machines installed at railways stations were used. The crushed bottles were washed, dried and fed into a mild steel pyrolysis reactor unit. The schematic diagram of the pyrolysis process is given in Figure 1. The pyrolysis reactor used was a fully insulated cylindrical chamber of inner diameter 300 mm and outer diameter 310 mm and height 600 mm. A pressure gauge to measure the reactor pressure was mounted on the top of the reactor. Vacuum was created in the pyrolysis reactor by supplying nitrogen from the inert gas cylinder. For heating of reactor the outer surface was covered with auxiliary heater made of Nichrome wire rounded around the reactor. Auxiliary heater is designed to give peak power up to 10 kW and power can be adjusted using an autotransformer. A thermostat was used to control the temperature of the reactor. The process was carried out between 400 °C and 600 °C in the reactor for 5 hour. Initially for one hour temperature is kept near 400 °C then it is increased and maintains at 600 °C. The products of pyrolysis in the form of vapour were sent to a water cooled condenser and the condensed liquid was collected as a fuel. Water was continuously circulated through the inlet of water condenser and left the condenser through the water outlet. Condensed oil was collected in an oil collection tank. The oil was drained through the outlet of the oil collection tank. Non-condensable gases were collected in a gas bag.



1. Pyrolysis Reactor (with auxiliary heater); 2. Pressure Gauge 3. Condenser; 4. Oil Collector; 5. Gas Flow Meter 6. Gas collector

Figure 1: The schematic diagram of the pyrolysis process

The non-condensable gases were let out to atmosphere. The CPO collected was crude in nature. For an output of 1 kg of CPO about 1.75 kg of crushed plastic bottles feedstock was required. The products yielded from the process are: pyrolysis oil (50%), gas products (42%) and char (8%). The heat energy required to convert the crushed plastic bottles into the products was around 7.95 MJ kg^{-1}. The elemental composition of CPO is given in Table 1. Since the oil collected for this study was untreated, the CPO contains low and high volatile fractions.

Table 1: Consumption of petroleum products, 2001-02 to 2030-31(10^6×t)

Product	Actual Consumption				Protection	
	2001-2002	2004-2005	2008-2009	CAGR 2002-09	2020-2021	2030-2031
MS	7	8.3	11.3	7	25.4	49.9
HSD	36.5	39.7	51.7	5.1	93.5	153.4
SKO	10.4	9.4	9.3	-1.6	7.6	6.5
LPG	7.7	10.2	12.2	6.7	26.6	51.1
Sensitive product	61.7	67.5	84.4	4.6	144.4	22.6
Free industrial product	38.7	44.1	49	3.4	73.3	102.6
Total	100.4	111.6	133.4	4.1	217	325.6

3. Results and Discussion

Properties of dissipated containers pyrolysis oil obtained in laboratories are analysis and compared with typical diesel fuel. The liquids obtained are dark brown colored products, resembling petroleum fractions. The carbon residue result for the dissipated containers oil is 0.75%.The carbon residue test is a measure of the tendency of the oil to form carbon, particularly when the oil is combusted in the absence of large excess air or when the fuel is subject to evaporation and pyrolysis. A high carbon residue result may lead to coking (formation of solid residue from oil) of fuel injector nozzles in a diesel engine or spray combustion orifices. The typical diesel fuel shown in Table 2 has a carbon residue of approximately 0.08% however; fuel oils used in very large diesel engines may have carbon residues up to12% (Williams et al., 1998), Cetane number or CN is a measurement of the combustion quality of diesel during compression ignition. CN is actually a measure of a fuel's ignition delay; the time period between the start of injection and the first identifiable pressure increase during combustion of the fuel. In a particular diesel engine, higher Cetane fuels will have shorter ignition delay periodsthan lower Cetane fuels. Cetane number of dissipated containers oil is 43 which is less than normal Cetane requirement. Bi-fueling or blending is the simplest technique for admitting

Table 2: Properties of container pyrolysis oil

Sl. No.	Standard euro iv Diesel (Bhatt P.M., Patel, 2012)		Diesel sample	CPO
	Characteristic requirement	Actual results	Actual results	Actual results
1.	Acidity mgKOH g^{-1}	Nill	Nill	Nill
2.	Ash (%), by mass	0.01	Nil	0.04
3.	Carbon Residue (%) By mass	0.3	0.08	0.75
4.	Cetane Number	51	52	43
5.	Cetane Index	46	48	38
6.	Density at 15 °C kg m^{-3}	820-845	828	880
7.	Kinematic Viscosity cSt at 40 °C	2.0-4.5	2.59	6.4
8.	C		86	84
9.	H		23	22
10.	S		0.32	0. 84
11.	N		Trace	Trace
12.	Water content mg kg^{-1}	200	Nil	Nil
13.	Copper strip corrosion	Not worse than 1	1a	1a
14.	Pour point, winter	3 °C	5 °C	6 °C
15.	CFPP	6 °C	5 °C	8 °C
16.	CV , kCal kg^{-1}		10800	10450
17.	PAH, % by mass	11	6	24
18.	Sediments, % by mass	Nil	Nil	Nil

fuels with low Cetane number in high compression engines. Generally, diesel engines run well with a CN from 40 to 55. The Kinematic viscosity of the dissipated containers oil is 6.4 cSt at 40 °C which is slightly higher than the limits specified for Euro IV diesel fuel. Viscosity affects injector lubrication and fuel atomization. Fuels with low viscosity may not provide sufficient lubrication for the precision fit of fuel injection pumps or injector plungers resulting in leakage or increased wear. Fuels which do not meet viscosity requirements can lead to performance complaints. Fuel atomization is also affected by fuel viscosity. Diesel fuels with high viscosity tend to form larger droplets on injection which can cause poor combustion and increased exhaust smoke and emissions. The flash point of a liquid fuel is the temperature at which the oil begins to evolve vapors in sufficient quantity to form a flammable mixture with air. The temperature is an indirect measure of volatility and serves as an indicator of the fire hazards associated with storage and application of the fuel. The flash point of the dissipated containers -derived oil is 32. The flash point is low when compared to petroleum refined fuel. But in general it is slightly lower than the limit specified for euro diesel. The low flash points of the dissipated containers oil were not surprising since the oil represents un-refined oil with a mixture of components having a wide distillation range. The carbon and hydrogen contents of the dissipated containers oil are comparable with that of diesel fuel. The sulphur content of the dissipated containers oil is 0.84% which is less than that found by other researchers. The sulphur content is found less than that of a light to medium fuel oil. Nitrogen content is found similar to that of diesel fuel but quite less than that of a light fuel oil and a heavy fuel oil. Higher nitrogen content of the fuel may contribute to the formation of NO_x on combustion. Water and sediment can and will cause shortened filter life or plugged fuel filters which can in turn lead to fuel starvation in the engine. In addition, water can have negative impact on fuel corrosion and on microbial growth which is found to be nil for the dissipated containers oil. The copper strip corrosion test indicates potential compatibility problems with fuel system components made of copper, brass or bronze. The limit requires that the fuel not darken these parts under the test conditions. Pour Point is the temperature at which fuel thickens and will not pour and the value of pour point for dissipated containers oil is found to be 5 °C.Cold Filter Plug Point (CFPP) is the temperature at which fuel crystals have agglomerated in sufficient amounts to cause a test filter to plug. The CFPP is less conservative than the cloud point, and is considered by some to be a better indication of low temperature operability and is found to be 8 °C for the derived oil. The calorific value of the dissipated containersoil is 10450 kcal kg^{-1}. The calorific value is high and comparable with that of a diesel fuel oil, indicating the potential for the use of dissipated containers derived oils as fuel. Polycyclic Aromatic Hydrocarbons (PAHs) are a group of chemicals that occur naturally in coal, crude oil and gasoline. PAHs also are present in products made from fossil fuels. Some of the PAH have been shown to be carcinogenic and/or mutagenic. PAHs also can be released into the air during the incomplete burning of fossil fuels. The less efficient the burning process, the more PAHs is given off but studies have shown that combustion of dissipated containers oil with excess air results in negligible emissions of PAH. Since diesel engine always operates lean with combustion efficiency of 98% there may be less emission of PAH. Table 2 shows the concentration of the main PAH in the dissipated containers pyrolysis oil compared to the diesel fuel and is found to be 24% by mass for dissipated containers oil almost double the value of diesel (Kaminsky and Menzel, 2012).

4. Conclusion

Due to presence of sediments and contaminant, there is need to purify the pyrolysis oil for the use in diesel engine. Pyrolysis oil has certain properties which resemble with high speed diesel, thus the production of bio-fuel is a pioneering idea to solve energy crisis along with the waste management. We can also say that the pyrolysis oil can be used as alternate fuel with specific treatment and design modification of CI engine.

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