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Study of Tyre Pyrolysis Oil – Diesohol Blends

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Abstract*—This paper investigates the possibility of replacing diesel with an alternative fuel. The alternative fuels used in this paper are Tyre Pyrolysis Oil[TPO] and Distilled Pyrolysis Oils, of two different temperatures [DPO1 and DPO2]. The TPO, DPO1 and DPO2 are blended with diesel, of different concentrations, and butanol is added to the blends. The blends are tested for properties like Stability, Density, Specific Gravity, Viscosity, Flash point and Fire point and are compared with the base values of Diesel. The results of this investigation proves that the above made blends may be used as an alternative fuel for diesel in engines and automobiles, as they possess similar values when compared to diesel.*

Keywords— *Alternate fuel, Pyrolysis Oils, Recycle, Waste disposal*

I. INTRODUCTION

Rapid depletion of existing fossil fuels like diesel and petroleum, leads to the need for an alternative fuel, preferably not leading to the need for modifications in the automobile and machine engines. Improper waste disposal is also a threat to the living world. If these wastes can be converted to useful energy, a fuel that can replace diesel without the need for any modification of engines, a lot of good can be done to the environment. Fuels made from waste rubber/tyres, namely Tyre Pyrolysis Oil, are made by the pyrolysis of the rubber, and can replace diesel as engine fuel due to their similarity in properties. In this study, samples of Diesel-Butanol[Diesohol] with Tyre Pyrolysis Oil and Distilled Pyrolysis Oil are made and studied for their properties.

In a work by S Murugan et.al (3), the pyrolysis reactor used was a fully insulated cylindrical chamber. A vacuum was created in the pyrolysis reactor and then externally heated by means of a 1.5 kW heater. A temperature controller controlled the temperature of the reactor. The process was carried out at around 350^{o}C in the reactor for several hours. The. The TPO collected was crude in nature. For an output of 1 kg of TPO, about 2 kg of waste tyre feedstock was required. The products yielded from the process were: TPO (50%), pyro gas, steel wire and carbon black.

Vacuum distillation process was carried out to separate the lighter and heavier fraction of hydrocarbon oil [1]. A known sample of TPO was taken for vacuum distillation process. The sample was externally heated in a closed chamber and the DTPO was collected separately.

In the study by Chaala and Roy (13), it was mentioned that the used tyres were thermally decomposed at 500^o C at a total pressure of 20 kPa in a process development unit consisting of a horizontal reactor vessel 3 m long and 0.6 m in diameter. The chemical composition of the tyre pyrolysis oil was: carbon (86.51%), hydrogen (10.10%), nitrogen (1.2%), sulphur (0.8%), and oxygen (by difference) (1.39%). Comparison between two pyrolytic oils derived from passenger car tyres and truck tyres from a fixed bed reactor have been done before by Ucara et.al [14] ; At an optimum temperature of 650 ^{o}C, the chemical composition of tyre pyrolysis oil derived from truck tyres was: carbon (86.47%), hydrogen (11.73%), nitrogen (<1%), sulphur (0.83%), ash (<1%), and oxygen (not calculable). The chemical composition of tyre pyrolysis oil derived from waste automobile tyres from bomb reactors was: carbon (86.11%), hydrogen (10.92%), nitrogen (0.41%), sulphur (0.83%), ash (not available), and oxygen (calculated by difference) (1.73%).

For many years, research has been conducted on this field to replace the rapid depleting fossil fuel with both renewable and non-renewable, including solar/wind power, electricity, usage of bio-waste/biomass as biodiesel and even non -biodegradable wastes like plastic, rubber, etc. The TPO used here was made by pyrolysis of waste tyres at 350^{o}C, with a hydrocarbon gas, carbon black and steel wire as by products. The DPO1 was distilled at a temperature range of 180-220^{o}C and DPO2 at 275^{o}C.

Research works conducted by Alen C Hansen et.al [2] proves the similarity in properties and effectiveness of using alcohols like ethanol with diesel [7]. Butanol has more combustion energy than ethanol, while it has a low volatility than ethanol. Thus we have used Butanol as a replacement for Alcohol in this experiment. Works by Zehra Sahin et.al [4] stands as a proof that the blend of Diesel and Alcohol, called as Diesohol can be used in Diesel Engines. The research paper done by Cumali Ilikilic et.al [5] proves the production of fuel from waste tyre by pyrolysis, and its application in diesel engines possible. Also the works done by G Nagarajan et.al proves the effective usage of tyre pyrolysis oil and distilled pyrolysis oil in diesel engine without much modification in the diesel engine[1,3]. Taking all these into account, we have come up with this study of using TPO and DPO and their blend with diesohol blends.

The pyrolysis oil and distilled pyrolysis oil used in this experiment was provided by a commercial exporter of the same, Mandakan Energy, Palakkad, Kerala.

II. Experiment

1. Preparation of sample :

The required amount of sample is prepared by blending the required proportions of the TPO/DPO1/DPO2 with Diesohol. The samples were made with the following volume % for testing :

(i) 50% TPO, 45% Diesel, 5% Butanol
(ii) 25% TPO, 25% DPO1, 45% Diesel, 5% Butanol
(iii) 25% TPO, 25% DPO2, 45% Diesel, 5% Butanol
(iv) 50% DPO1, 45% Diesel, 5% Butanol
(v) 50% DPO2, 45% Diesel, 5% Butanol
(vi) 25% DPO1, 25% DPO2, 45% Diesel, 5% Butanol
(vii) 25% TPO, 25% DPO1, 25% DPO2, 20% Diesel, 5% Butanol
(viii) 100% Diesel

2. Measuring the properties :

The samples created above are subjected to various tests for evaluating the properties like Stability, Density, Specific Gravity, Viscosity, Flash point, Fire point, and Calorific value and are compared with the properties of 100% diesel as base.

III. Results

A. Stability

The samples made were stable when the used alcohol was over 90% by weight, and after a certain increase in the concentration of water, layer separation occurs. The blends are perfectly miscible at room temperatures and with minimal amount of water in the butanol

B. Density

500 mL of the samples were taken and their weights were measured. Using the formula, Density = Mass/Volume, the densities were calculated from which specific gravity[SP] can be calculated.

C. Viscosity

The samples were subjected to test in a Redwood Viscometer and their corresponding Redwood seconds[R] were noted. The viscosities were calculated using the formula:

Kinematic Viscosity,
$Z_k = 0.264R - 190/R$ centistokes ; $40s<R<80s$
$0.247R - 65/R$ centistokes ; $80s<R<2000s$
where R is the Redwood seconds.
Absolute Viscosity,
$Z_{Ab} = Z_k$ * Specific Weight units

D. Flash and Fire point

The samples were taken in a Cleveland Apparatus, and they were subjected to test and their Flash and Fire points were noted using the temperature reading in the thermometer.

Table 1	**PROPERTIES**		
BLEND NO.	**DENSITY [kg/m^3]**	**SPECIFIC GRAVITY**	**KINEMATIC VISCOSITY [centistokes]**
1	1148.82	1.1508	3.54
2	1116.6	1.1186	3.61
3	1071.94	1.0738	2.05
4	1099.8	1.1017	3.81
5	1091.6	1.0935	1.25
6	1112.2	1.1142	2.28
7	1114.4	1.1163	3.18
8	832	0.8334	2.05

Table 2	**PROPERTIES**	
BLEND NO.	**FLASH POINT [^{o}C]**	**FIRE POINT [^{o}C]**
1	52	54
2	55	57
3	53	54
4	51	53
5	49	50
6	46.5	47
7	47	47.5
8	49	52

IV. Conclusion

The results and values from the tables 1 and 2 were analysed and the following were the concluded.

1. The samples were found to be stable when the water content is minimum.

2. The density of the tyre oils were a little higher than that of diesel.
3. The values of kinematic viscosity were in the range specified for automobile fuels of 2-5 cSt.
4. The Flash and Fire point were similar to that of pure diesel.

The higher density of the pyrolysis oils may be attributed to the presence of aromatic contents in more concentration than that present in diesel. It may also be due to the presence of Sulphur compounds in the oils. The same contributes to the viscosity of the pyrolysis oils. The source of the Sulphur is from the vulcanized rubber tyres used in the process.

The values obtained from the various tests conducted in evaluating the properties show that the values of the corresponding properties of the blends were in range to that of diesel. The similarity in the values indicates that the TPO can be used as an alternative for diesel as a fuel or can be made into a blend with diesel. Since no engine tests has yet been performed by us, but was done in a different work by G Nagarajan et.al [3], the efficiency and emission characteristics should be of comparable values as well as the diesel engine can be worked with the pyrolysis oil without any modification [3]. The brake thermal efficiency for diesel at full load is 29.5%, while that with 50% by vol TPO and diesel is 28.9% at full load. With 20% by vol DTPO and 80% Diesel, the brake thermal efficiency is 28.5%[1]. From the experiment, we can conclude that by removing the aromatic components and the sulphur compounds from the pyrolysis oils by desulphurisation processes, we can achieve an alternate fuel of comparable quality and efficiency as a replacement for diesel.

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