



Characterization of alumina catalyst in the catalytic fuel reformer

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Abstract: The catalytic fuel reformer (CFR) is investigated in this study. Waste engine oil (WEO) is used as the fuel for CFR and alumina is used as the catalyst to crack the WEO. The reformulated gas is condensed using water cooled condenser and analyzed to know the suitability of using this reformulated gas in the compression ignition engine. The condensed reformulated gas is named as WEOA. The different properties such as specific gravity, kinematic viscosity, flash and fire point, gross calorific value, pour point, density of WEOA is analyzed and compared to that of diesel fuel and found that all the properties are closer to that of diesel fuel. WEOA is characterized by GC-MS and the result revealed that the heavier hydrocarbon presents in the WEO are cracked into light hydrocarbon because of the catalysts alumina and which is similar to that of diesel fuel. The FT-IR analysis was also conducted and the result revealed that the major transmittance spectrum peak are acorns and the presence of the hydrocarbon is clearly seen in the WEOA. Based on the investigation, it is suggested that WEOA has a potential to be used as alternate fuel for diesel engine. Hence an environmentally unfriendly WEO can be recycled into a useful resource and serves as an alternative source of fuel for diesel engine.

Keywords: Waste engine oil, fuel reformer, pyrolysis, alumina, catalyst

I. INTRODUCTION

Exhaustible fossil fuel reserves and steep climb in fuel price has resulted in a continuous hunt for potential alternative fuels for internal combustion engines. The search is very particular to find suitable alternative fuels for compression ignition engines (CI) as they are widely used in many applications. The production of waste engine oil was estimated as 24 millions of tons per year around the world. The disposing of waste engine oil is a serious event for the environment because of its hazards in nature. Early method of discarding the waste engine oil such as incineration, combustion for energy recovery, vacuum distillation and hydro treatment is likewise experiencing the problem of throwing away the sludge as the terminal product of these processes [1-3]. Waste engine oil contains a variety of aliphatic and aromatic hydrocarbons [4] and hence already been investigated as the alternate fuel for the compression ignition engine [5] which increases the brake thermal efficiency and cuts back the specific fuel consumption.

Pyrolysis techniques as an economic and environmental friendly method of recycling the waste engine oil [6-8] into useful alternate fuel for compression ignition engine. The waste material was thermally cracked and decomposed in an inert atmosphere, with resulting pyrolysis oils and gases able to be used as a fuel. The oil can be catalytically upgraded or refined in the petroleum processing industries for further process [9]. In this operation, the waste engine oil was thermally cracked in the catalytic fuel reformer (CFR). As a consequence of heating the oil is thermally cracked in the absence of oxygen into shorter hydrocarbon chains.

The composition of and physiochemical properties of pyrolysis oils vary and mostly depend on the feedstock used and processing technology employed. The features of these oils directly relate to their behavior in fuel systems and locomotive operation. Thus, it is indispensable to carry out characterization and evaluation of pyrolysis oils before their employment as an engine fuel. The fuel injection characteristics such as injection timing, injection pressure and injection duration largely depend on the oil density and viscosity because of their influence on oil atomization effects during injection [10,11]. Early research proves that a relatively low density of the oil retarded injection timing, while a relatively low viscosity results in an advanced timing because of less friction produced by the oil travelling through the nozzle [11, 12].

Aluminum oxide, Al_2O_3 is a major engineering material. It offers a combination of good mechanical properties and electrical properties leading to a wide range of applications. Its high hardness, excellent dielectric properties, refractoriness and good thermal properties make it the material of choice for a wide range of

applications. In its largest scale application, aluminium oxide is the catalyst in the Claus process for converting hydrogen sulfide waste gases into elemental sulfur in refineries. It is also useful for dehydration of alcohols to alkenes. Aluminium oxide serves as a catalyst support for many industrial catalysts, such as those used in hydrodesulfurization and some Ziegler-Natta polymerizations.

The purpose of the present investigation is to detect the suitable alternate fuel for compression ignition engine and also disposing the waste engine oil (WEO) the hazardous waste in nature by reuse it as substitute fuel. Hence this study investigates the characterization of the WEO after it was heated in the CFR, to know the suitability as alternate fuel in compression ignition engine. This work also traces the influence of the catalyst alumina used on the CFR. Some of the significant attributes of the oil are broken down and compared to those of conventional diesel fuel.

II. MATERIALS AND METHODS

A. REFORMULATED FUEL PRODUCTION SYSTEM

A CFR was designed and fabricated to convert the WEO into diesel like fuel. The reformer is installed in the Engine Research Laboratory, Department of Mechanical Engineering, Annamalai University. Schematic representation of the system is shown in figure 1.

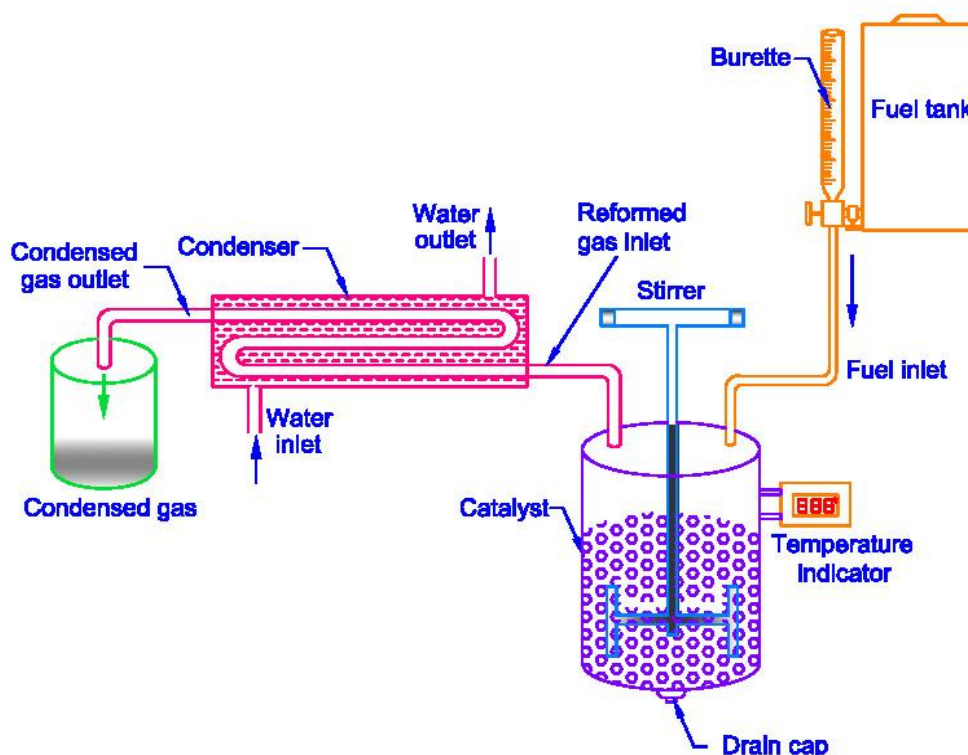


Figure 1. Catalytic Fuel Reformer

The system consisted of several components such as fuel tank, control panel, reactor, thermocouple, stirrer, condenser, fuel storage tank. The fuel tank is used to supply the WEO into the reactor. The reactor of the system has a cylindrical shape with inner diameter of 15cm and the length of 45cm. The reactor was designed and fabricated to heat the WEO along with the catalyst. It includes an electrical heating unit which can be employed to heat the WEO with catalyst upto 1000oC. The electric heater has resistance heater and a voltage control which is used to adjust the heating rate. The heating control is done by the control panel. The stirrer is used to mixing the WEO with catalyst uniformly and also to distribute the temperature uniformly. The thermocouple is used to measure the temperature in the reactor. The condenser unit is used to condense the reformulated gas from the reformer. Alumina pellets of 2 to 5 mm diameter is used as catalyst in the CFR. The CFR is set to 300°C. The condensed reformulated gas is named as WEOA.

B. COMPOSITIONAL ANALYSIS

B.1. GC-MS

Liquid samples were dissolved in methanol and analyzed using GC-MS instrument (Varian-Saturn-2200 MS/MS). The GC-MS was operated in non-isothermal mode, ramping at 250 °C using a 30 m fused silica capillary column (cross linked 5% PH ME siloxane, I.D. 0.25 mm film thickness 0.25 µm).

The total ion chromatogram produced for each sample was analyzed using Varian analysis software and the NIST mass library. The chromatograph integrator was programmed in two different modes, allowing the quantification of compounds by both species and size. In this manner, a single GC-MS analysis permitted the identification of the products and the categorization of the sample by chain length. The GC-MS was not calibrated for the individual compounds in the samples; hence, the compounds are quantified as total ion content percentage (TIC%) - an integration of the chromatogram peaks.

B.2. FT-IR

A Bruker-Alpha FT-IR spectrometer with a resolution of $\pm 1 \text{ cm}^{-1}$ was used. Spectra were recorded at room temperature (298 K) in the region of 4000 to 400 cm^{-1} and NaCl cell of path length 0.1mm was used. The spectrometer possesses auto align energy optimization and dynamically aligned interferometer. It is fitted with a KBr beam splitter, a DTGS-Detector and Everlgo™ mid-IR source. A baseline correction was made for the spectra recorded.

III. RESULT AND DISCUSSION

A. FUEL CHARACTERIZATION

Fuel properties like density, kinematic viscosity, flash point, fire point, calorific value and specific gravity are analyzed for FEO, WEO, WEOA and compared it to that of diesel fuel. The density is evaluated according to ASTM D1298 method, kinematic viscosity is measured according to ASTM D445 method, flash level and fire point are measured as per ASTM D93, calorific value is assessed as per ASTM D5865 method, specific gravity is measured as per ASTM D1298 method and calorific value is assessed as per ASTM D240. Some of the important properties of diesel fuel, FEO, WEO and WEOA are shown in table 1.

Table 1 Properties of diesel, WEO and WEOA

Property	Diesel	WEO	WEOA
Specific gravity @ 27°C	0.8298	0.879	0.9098
Kinematic viscosity @40°C in CSt	2.57	52	11.10
Flash Point in°C	50	197	30
Fire Point in °C	56	-	33
Gross calorific value in MJ/kg	44.67	45.4	45.13
Density@15°C in gm/cc	0.8072	0.858	0.9090

B. CHEMICAL COMPOSITION

B.1 GC-MS

WEOA is characterized by GC-MS. The results of GC-MS analysis was shown in figures 2. The GC-MS result revealed that the WEO containing $C_{11} - C_{40}$ hydrocarbons, was thermally cracked with alumina catalyst to WEOA comprising mainly of $C_5 - C_{30}$ hydrocarbons and which are dominated by aliphatic hydrocarbons and significant amounts of aromatic. This indicates the occurrence of cracking of compounds to produce some aromatic structures. Perhaps derived from cyclisation and aromatization reactions that occurred during pyrolysis. The aliphatic hydrocarbons were mostly alkanes. These aliphatic hydrocarbons, particularly the $C_5 - C_{20}$ aliphatic fractions, represent a potentially high value fuel source.

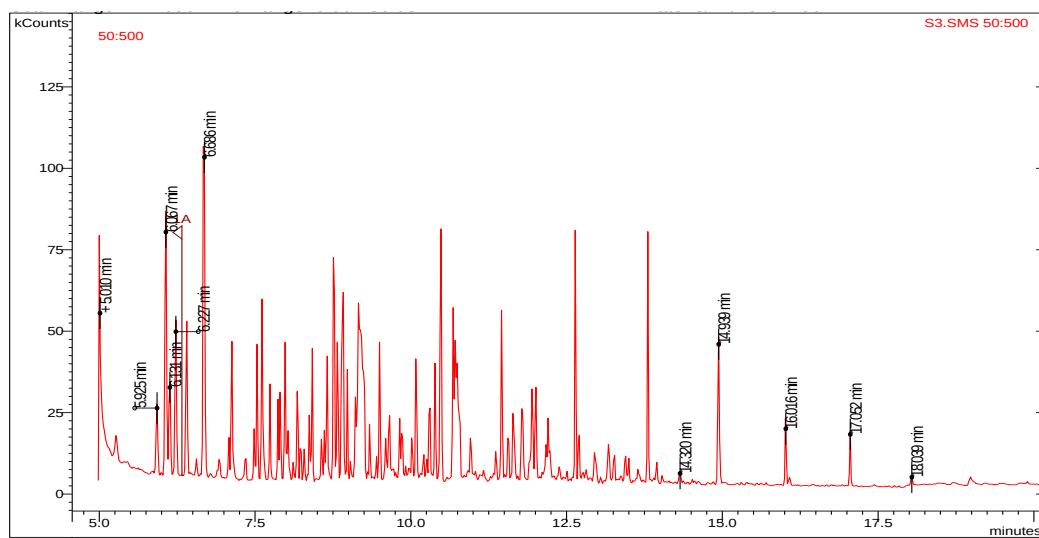


Figure 2 GC-MS of WEOA

B.2 FT-IR

FT-IR spectroscopy was used to identify the functional groups present in waste engine oil and it can offer information regarding the chemical change of the functional groups which may play an important role in investigating the influence of catalyst with waste engine oil. The representative FT-IR spectra of the WEOA is shown in figure 3.

Typical infrared absorption bands of hydrocarbons can be observed. Example, between 3000 and 2800 cm^{-1} the presence of C-H stretching vibration of $-\text{CH}_2-$ and $-\text{CH}_3$ groups was blamed for infrared activity. On the other hand significant differences between the ratio of $-\text{CH}_2-$ and $-\text{CH}_3$ groups can be observed, because the intensity of asymmetric stretching, vibration bands at 2926 cm^{-1} and 2962 cm^{-1} is the proportional number of $-\text{CH}_2-$ and $-\text{CH}_3$ groups, respectively.

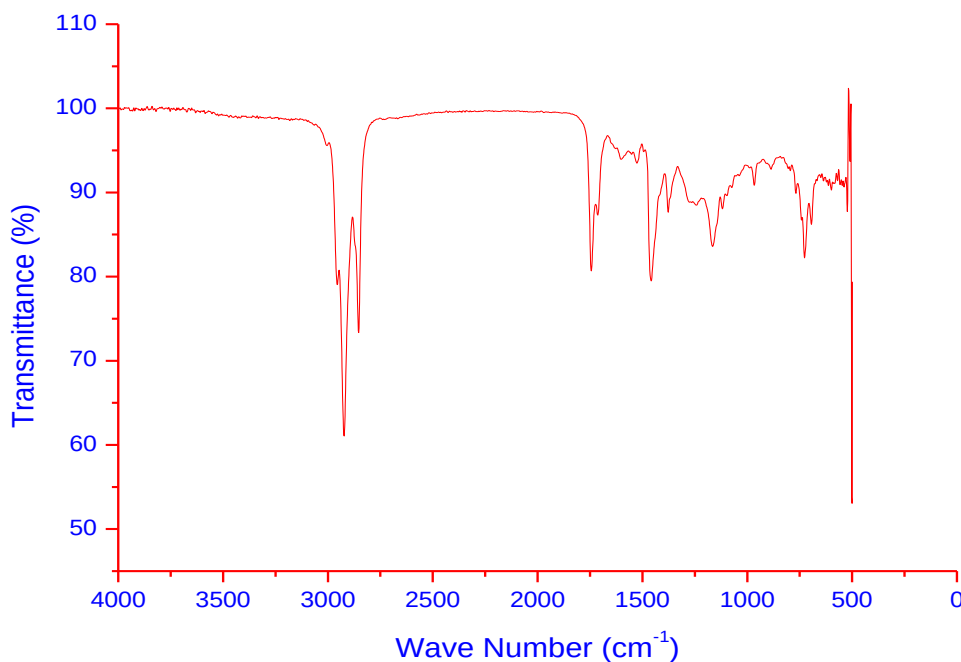


Figure 3 FT-IR of WEOA

The infrared activity in the wave number range of 1470 – 1430 cm^{-1} and 1395 – 1365 cm^{-1} was caused by the asymmetric and symmetric deformation stretching of $-\text{CH}_3$ groups. One band was found in the range of 1650 – 1750 cm^{-1} , which could be occurred from the vibration of benzene derived aromatic compounds. It is known that the position of that peak varies with the structure of subsistence. In the wave number range of 800 – 1000 cm^{-1} , the C-H stretching vibrations caused infrared bands at 910 and 990 cm^{-1} from the vinyl type double bonds, at 890 cm^{-1} from the vinylidene and at 956 cm^{-1} from the internal positioned double bonds. Infrared band in the range of 800 – 500 cm^{-1} is induced by the mowing vibration of $-\text{CH}_2-$ groups and the aromatic. Hence FT-IR results confirmed that most of the hydrocarbons found in the WEOA are alkanes and thus a potential to be used as alternate fuel in diesel engine.

IV. CONCLUSION

Alternate fuel for diesel engine is the important factor of the environment due to the diminishing of fossil fuels, increasing price and awareness of the increased environmental consequences of emissions from diesel engines. In the present study, the possibility of using WEO as diesel like fuel was investigated. The collected WEO was allowed into the CFR. Two different catalysts red mud and fly ash were used in this investigation. The reformed gas from the CFR was condensed using condenser and the sample was analyzed. The following results were obtained:

1. Characteristics of the reformulated fuel, such as density, flash point, fire point, viscosity, calorific value is tested and found to be close to that of the diesel fuel.
2. Alumina is used as catalysts. Based on their individual properties of the catalyst, it efficiently utilized to convert the WEO into diesel like fuel.
3. The GC-MS results revealed that the heavier hydrocarbon presents in the WEO were cracked into light hydrocarbon because of the catalysts alumina and which is similar to that of diesel fuel.

4. FT-IR results confirmed that most of the hydrocarbons found in the WEOA are alkanes and thus a potential to be used as alternate fuel in diesel engine.

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