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BEHAVIOUR OF ZEOLITE 4A IN THE EXTRACTION PROCESS OF THE DIESEL LIKE FUEL OBTAINED FROM WASTE ENGINE OIL

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Abstract

The aim of the present study is to recycle and reuse the WEO as an alternative fuel for compression ignition (CI) engine. For this purpose the WEO was cracked in the catalytic fuel reformer by using the catalyst zeolite 4A. The output of the catalytic fuel reformer is in the gaseous form which is condensed using water cooled condenser. The oil obtained after condensing the reformulated gas is named as WEOZ. To know the suitability of using the WEOZ as alternate fuel for IC engines, the different properties of WEOZ were determined. The different properties include specific gravity, kinematic viscosity, flash and fire point, gross calorific value, pour point, density. The properties of WEOZ were compared to that of diesel fuel. All the fuel properties are closer to that of the neat diesel fuel. The FTIR analysis was also be conducted for diesel and WEOZ. The result of FTIR analysis was compared to that of diesel fuel. The FTIR result revealed that the major transmittance spectrums peak for diesel and WEOZ were alkanes and the presence of the hydrocarbon was clearly seen in the WEOZ. Based on this investigation, it was suggested that WEOZ 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, Diesel like fuel, pyrolysis, Zeolilte, Catalyst.

1. Introduction

The depletion of convention fossil fuels, growing of air pollution caused by combustion of fossil fuels and their increasing cost make alternative fuel sources more attractive [1]. WEO is an environmentally hazardous, high volume waste that

Abbreviations

ASTM	American Society for Testing and Materials
CI	Compression Ignition
Cst	Centistoke
DTGS	Deuterated Tryglycine Sulfate
FCC	Fluid Catalytic Cracking
FEO	Fresh Engine Oil
FTIR	Fourier Transform Infrared
IC	Internal Combustion
IR	Infrared
LOI	Loss of Ignition
SCR	Selective Catalytic Reduction
WEO	Waste Engine Oil
WEOZ	Waste Engine Oil Cracked with Zeolite 4A Catalyst

is difficult to treat and dispose of due to the presence of undesirable species such as soot, polycyclic aromatic hydrocarbons and impurities from additive such as chlorinated praffins and poly chlorinated biphenyls [2]. The production of WEO is estimated as 24 million tons per year throughout the world, posing a significant disposal problem for modern society [3].

WEO treatment process such as incineration, hydro treating, etc are practically not feasible and it creates further more environment pollution and addition sludge [4, 5]. Wastes are processed to be used fuel or converted into various chemicals to minimize the harmful effects [6l]. However the most important elements that make it difficult to recycle the waste oils for various purposes [7].

Production of diesel like fuel from waste oil such as industrial and engine waste oils, wood pyrolysis oils, fresh and waste fats and vegetable oils is an excellent way for producing alternate fuel source, wood pyrolysis oil [8], animal fat and vegetable oil [9], industrial and engine waste oil [3] have been proposed for the pyrolysis process to produce the diesel like fuel.

It has been four decades since the introduction of the shape-selective character of zeolites into industrial applications. In these four decades utilization of zeolites in catalysis has increased dramatically. Consumption of zeolites as catalysts accounts for an estimated 27% of the world zeolite market on a value basis. Fluid catalytic cracking (FCC) catalysts constitute more than 95% of zeolite catalyst consumption. Overall, the worldwide zeolite catalyst consumption sums up to approximately 241 thousand metric tons per year [10].

In refineries consumption of zeolite catalysts has increased as a result of the environmentally driven policies to decrease sulphur emissions. Also, in order to enhance the light olefin yields, the FCC catalyst compositions were modified by increasing the zeolite loadings and by introducing different types of zeolite structures [11, 12]. Zeolites have also replaced the conventional catalysts in many industrial processes as the environmentally benign alternatives. With increasing environmental regulations to fight air pollution, new applications opened up for zeolite catalysts. In Europe, North America and Japan progressively more and stricter regulations are being implemented to reduce the NOx emissions from stationary and mobile applications. The chemical composition of zeolite 4A is shown in the Table 1.

Zeolites are the preferred catalysts for diesel Selective Catalytic Reduction (SCR) as they can withstand high operating temperatures, which is essential in automotive SCR applications. This is a highly effective catalytic system as the zeolite catalyst can convert most of the NOx during steady-state operation. With upcoming regulations on automotive NOx emissions, the new generation of both light-duty and heavy-duty diesel vehicles will utilize this technology. Therefore, a significant zeolite catalyst demand from the automotive industry can be forecasted.

Table 1. Composition of zeolite 4A.

Components	Zeolite 4A
SiO_2	33.30
Al_2O_3	27.65
Fe_2O_3	0.39
TiO_2	0.18
Na_2O	20.02
K_2O	<0.1
LOI	18.43

2. Experimental Setup and Procedure of Experimentation

2.1. Catalytic thermal reactor

A catalytic thermal reactor was designed and fabricated to convert the WEO into diesel like fuel. The reactor was installed in the Engine Research Laboratory, Department of Mechanical Engineering, Annamalai University. Photographic view of the system was shown in Fig. 1 and schematic representation was shown in Fig. 2.

The system was 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 used to heat the WEO with catalyst upto 800^{o}C. The electrical heater has resistance heater and a voltage control which is used to adjust the heating rate. The heating control is performed by 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 reformed WEO gas from the reactor. A water cooled condenser was used to condense the reformed WEO gas.

500 ml of WEO is used for a cycle. 3 kilo grams of zeolite catalyst are used in the reactor. The temperature of the reactor is set to 300^{o}C. The WEO is allowed in the catalytic thermal reactor gradually while the temperature of the reactor increasing. Periodically the stirrer is used to mix the WEO with catalyst thoroughly and distribute the temperature in the reactor uniformly.

Fig. 1. Photographic view of the catalytic thermal reactor with condenser.

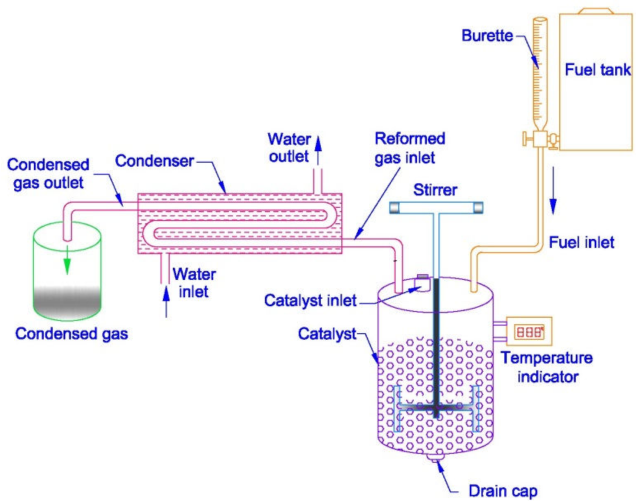

Fig. 2. Schematic diagram of the catalytic thermal reactor.

2.2. Analysis of samples

2.2.1. Fuel characterization

In this section the different fuel properties include Specific gravity, kinematic viscosity, flash and fire point, gross calorific value, density and FTIR are discussed. The specific gravity was determined according to ASTM D1298 method, kinematic viscosity was determined as per ASTM D445 method, flash and fire point were determined according to ASTM D92, gross calorific value was determined as per D240 method, density was measured according to the ASTM D1298 method.

2.2.2. Fourier transform infrared (FTIR) spectra for neat DF and WEOZ

The aim of the current investigation is to find the suitable alternate fuel for CI engine. To fulfil the aim WEOZ is selected as a possible source for alternative fuel. However, it is necessary to examine WEOZ's suitability as CI engine's fuel. Considering the above fact, FTIR analysis of WEOZ was performed as FTIR gives an idea about the suitability of WEOZ as diesel fuel. FTIR helps to identify the basic compositional groups of the WEOZ. The FTIR instrument produces the IR-spectra of the WEOZ. It provides the absorption spectrum in percentage incident intensity, along the wave numbers 4000 to 500 cm^{-1}. The standard IR-spectra of hydrocarbons were used to identify the functional group of the components of the WEOZ. The IR-Spectra of WEOZ was compared to that of diesel fuel.

A Bruker-Alpha FT-IR spectrometer with a resolution of ±1 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 was fitted with a KBr beam splitter, a DTGS-Detector and Everlgo™ mid-IR source. A baseline correction was made for the spectra recorded.

3. Result and Discussion

Viscosity is one of the important properties for diesel fuel as it affects fuel atomization. Some selected properties of diesel fuel, fresh engine oil (FEO), WEO and WEOZ were shown in Table 2.

Table 2. Properties of diesel fuel, FEO, WEO, WEOZ.

Property	Measurement Standards	Diesel	FEO	WEO	WEOZ
Specific gravity @ 27°C	ASTM D1298	0.8298	0.881	0.879	0.831
Kinematic viscosity @40°C in CSt	ASTM D445	2.57	85	52	2.25
Flash Point in°C	ASTM D92	50	215	165	48
Fire Point in °C	ASTM D92	56	-	-	74
Gross calorific value in MJ/kg	ASTM D240	44.67	43.6	45.4	41.23
Density@15°C in gm/cc	ASTM D1298	0.8072	0.879	0.858	0.813

The WEO shows a lower density but higher calorific value than that of the FEO. It is thought that some of the heavier hydrocarbons in raw oil are decomposed into lighter hydrocarbons in waste oil. The lower calorific value of the raw oil is likely due to the presence of carbon and long-chain carbon compounds of lower calorific value in the oil matrix. The density and viscosity of the WEOZ was found to be lower than that of the WEO due to the cracking of heavy hydrocarbons to lighter compounds. The density of WEOZ was quite close to that of diesel. The flash point of WEOZ was found to be lower than that of diesel. The low flash point suggests that the WEOZ contained components that have a lower boiling point range than diesel. The WEOZ posses lower kinematic viscosity than that of diesel, since lower viscosity is desirable and represents a favourable feature when it comes in handling.

The FTIR spectrums of diesel fuel and WEOZ were recorded and shown from Fig. 3. For diesel fuel the strong absorbance frequencies 2921.40 and 2853.56 cm-1 represents C-H stretching. The absorbance peak 1459.56 cm-1 showed the C-H bending which indicates the presence of alkanes. For WEOZ the strong absorbance 2922.21 and 2853.32 cm-1 shows the C-H stretching. The absorbance peak 1459.63 cm-1 shows the C-H bending which represents the presence of alkanes. From the FTIR graph it is clearly seen that the major transmittance spectrums peak for diesel and WEOZ are alkanes. The presence of saturated hydrocarbon is clearly seen from the above discussion. C-H indicates the presence of hydrocarbon and thus has a potential to be used as alternate fuel in diesel engine.

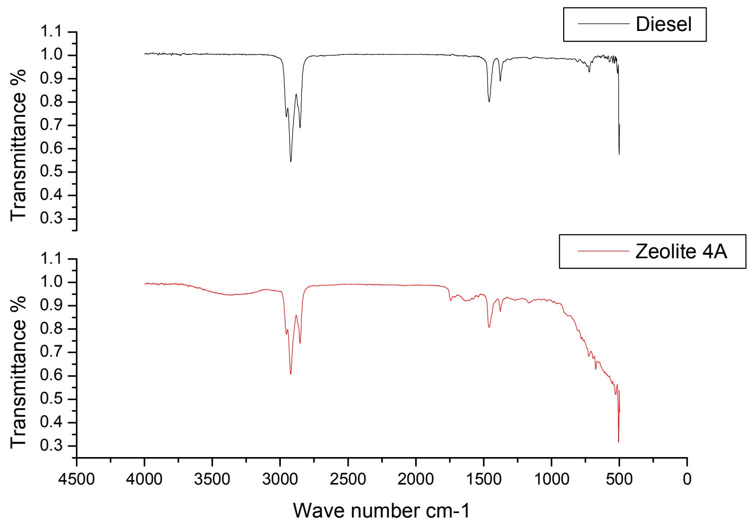

Fig. 3. FTIR Spectra of Diesel fuel and Zeolite 4A.

4. Conclusion

Alternative fuel for diesel engine is the important factor because of the depletion of convention fossil fuels, growing of air pollution caused by combustion of fossil fuels and their increasing cost. In this present investigation, the possibility of using WEO as diesel like fuel was investigated. The catalytic thermal reactor is used to crack the WEO into useful form of energy. The catalyst zeolite 4A was used in this investigation to crack the WEO in the catalytic thermal reactor. Based on the analysis of the properties it is concluded that the properties of the diesel and WEOZ were found to be very closer. Similarly, the FTIR result shown that the major transmittance spectrums peak for diesel and WEOZ were alkanes and the presence of the hydrocarbon was clearly seen in the WEOZ. Thus WEO was able to convert into diesel like fuel by the way of cracking the WEO using the catalyst zeolite 4A in the catalytic thermal reactor. Hence it is concluded that WEOZ had a potential to be used as alternate fuel in diesel engine, however further experimental investigation has to be carried out to know the performance of the engine.

References

1. Arpa, O.; Yumurutas, R.; and Argunhan, Z. (2010). Experimental investigation of the effects of diesel like fuel obtained from waste lubrication oil on engine performance and exhaust emission. *Fuel Processing Technology*, 91(10), 1241-1249.
2. Lam, S.S.; Russell, AD.; and Chase, H.A. (2010). Microwave pyrolysis, a novel process for recycling waste automotive engine oil. *Energy*, 35(7), 2985-2991.
3. Gomez-Rico, M.F.; Martin-Gullon, I.; Fullana, A.; Conesa, J.A.; and Font, R. (2003). Pyrolysis and combustion kinetics and emissions of waste lube oils. *Journal of Analytical and Applied Pyrolysis*, 68-69, 527-546.
4. Kim, S.-S.; Chun, B.H.; and Kim, S.H. (2003). Non-isothermal pyrolysis of waste automobile lubricating oil in a stirred batch reactor. *Chemical Engineering Journal*, 93(3), 225-231.
5. Brinkman, D.W.; and Dickson, J.R. (1995). Contaminants in used lubricating oils and their fate during distillation/hydrotreatment re-refining. *Environmental Science and Technology*, 29(1), 81-86.
6. Mastrral, A.M.; Callen, S.; Garcia, T.; and Navarro, M.V. (2000). Improvement of liquids from coal-tire co-thermolysis characterization of the obtained oils. *Fuel processing Technology*, 68(1), 45-55.
7. Bhaskar, T.; Uddin, M.A.; Muto, A.; Sakata, Y.; Omura, Y.; Kimura, K.; and Kawakami, Y. (2004). Recycling of waste lubrication oil into chemical feedstock or fuel oil over supported iron oxide catalysts. *Fuel*, 83(1), 9-15.
8. Vitolo, S.; Bresci, B.; Seggiani, M.; and Gallio, M.G. (2001). Catalytic upgrading of pyrolytic oils over HZSM5 zeolite: behaviour of the catalyst when used in repeated upgrading-regenerating cycles. *Fuel*, 80(1), 17-26.
9. Fortes, I.C.P.; and Baugh, P.J. (2004). Pyrolysis–GC/MS studies of vegetable oils from Macauba fruit. *Journal of Analytical and Applied Pyrolysis*, 72(1), 103-111.
10. Lauriente D.H.; and Inoguchi, Y. (2005). *The chemical economics handbook, SRI consulting.* 599.1000 F, pp 6-8, 14.
11. Akpanudoh, N.S., Gobin, K.; and Manos, G. (2005). Catalytic degradation of plastic waste to liquid fuel over commercial cracking catalysts: Effect of polymer to catalyst ratio/acidity content. *Journal of Molecular Catalysis A: Chemical*, 235(2), 67-73.
12. Olazar, M.; Lopez, G.; Amutio, M.; Elordi, G.; Aguado, R.; and Bilbao, J. (2009). Influence of FCC catalyst steaming on HDPE pyrolysis product distribution. *Journal of Analytical and Applied Pyrolysis*, 85(1-2), 359-365.