

Waste Automotive oil as alternative fuel for IC Engine

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Abstract - The production of waste automotive engine oil (WAO) is predictable at 24 million tons each year throughout the world, posing an important treatment and disposal problem for modern society. On the other hand, Increase in energy demand, stringent emission norms and depletion of oil resources have led the researchers to find alternative fuels for internal combustion engines. WAO, covering a mixture of low and high molecular weight aliphatic and aromatic hydrocarbons, also represents a potential source of high-value fuel and chemical feedstock. This paper presents an extensive review of the scientific literature associated with various pyrolysis applications in waste to energy engineering and from pyrolysis process it can also be recognized that the process offers an exciting way to recover both the energetic and chemical value of the waste materials by producing potentially useful pyrolysis products suitable for future reuse. The study also involves performance analysis and emission characteristics of the diesel like fuel and gasoline like fuel comparing with petrol and diesel from various researchers.

Keywords—Waste automotive oil(WAO), Pyrolysis, Pyrolytic distillation, Catalytic Pyrolysis, Microwave Pyrolysis, Diesel like fuel(DLF), Gasoline like fuel(GLF)

1. INTRODUCTION

1.1 Automotive Waste Oil

Nowadays, we find increasing demand for lube oil use, which results in more waste lube oils. Waste lubricant oils are important alternative fuel sources proved to be the best substitutes for existing petro fuels, since waste generated oils represent more than 60% of used lubricant oils. Since the energy resources related to fossil fuels diminish and are limited, the research focuses on finding alternative energy resources and utilizing them. The recycling of the automotive waste oils and lubricants is an alternative for energy resources. The high-volume waste oils can be turned into valuable fuel products by refining and treating processes. Converting of the waste oils into diesel and gasoline-like fuels to be used in engines without disposing is very important. Consumption of the diesel like fuel and gasoline like fuels prepared from the waste automotive lube oils, and blending of the produced fuels with gasoline or turpentine decrease consumption of petroleum based fuels, protecting environment from toxic and hazardous chemicals. It also saves of foreign exchange, reduces greenhouse gas emissions and enhances regional development especially in developing countries [1,2].

1.2 Pyrolysis

Waste oils can be reconstructed chemically by being heated in an oxygen-free environment. This process is called pyrolysis, which is defined as chemical decomposition by the action of heat and refers usually to chemical decomposition of organic materials heated in an environment of insufficient oxygen for combustion. Pyrolysis process has certain advantages over other treatment methods of waste disposal. The most important advantage of this method is that it does not pollute the environment when carried out in an appropriate way, because pyrolysis products such as gases, liquid oils and carbonaceous residue can be used as fuels.

2. VARIOUS CONVERSION PROCESSES

2.1 Pyrolytic Distillation

The thermal energy is externally applied to the reactor in the case of conventional electric heating from which it heats all the substances in the reactor including the evolved pyrolysis-volatiles, the surrounding gases, and the reactor chamber itself. The electrical heater has resistance heaters, and a voltage control which is used to adjust the heating rate. The heating control is performed by the control panel.

2.2 Catalytic Pyrolysis

Catalytic cracking started around 1936 by exploiting the catalytic ability of certain chemically treated natural clays in converting heavier cuts of lower value (Reichle, 1988). Catalytic cracking of heavy petroleum cuts is as old as petroleum refining itself. Catalytic cracking breaks complex hydrocarbons into simpler molecules in order to increase the value and quantity of lighter, more desirable products and decrease the amount of residuals. This process rearranges the molecular structure of hydrocarbon mixtures to convert heavy hydrocarbons into lighter fractions such as kerosene, gasoline, LPG, heating oil, and petrochemical feed stocks. The most common process is fluid catalytic cracking, in which the oil is cracked in the occurrence of a finely divided catalyst that is maintained in an aerated or fluidized state by the oil vapors. The fluid catalytic cracking is one of the major processes, which effectively contributes to the gasoline pool (Gerritsen, 1988). The fluid catalyst is continuously circulated between the reactor and the regenerator using air, oil vapors, and steam as the conveying media. The catalysts used in refinery cracking units are typically solid materials (zeolite, Aluminum hydro silicate, treated bentonite clay, fullers earth, bauxite, and silica-

alumina) that come in the form of powders, beads, pellets, or shaped materials called extrudates. The spent catalyst is regenerated to get rid of coke that collects on the catalyst during the process. Spent catalyst flows through the catalyst stripper to the regenerator, where most of the coke deposits burn off at the bottom, where preheated air and spent catalyst are mixed. Fresh catalyst is added and worn-out catalyst removed to optimize the cracking process.

2.3 Microwave Pyrolysis

Pyrolysis using microwave heating is a relatively new process in which the, waste hydrocarbons are mixed with a highly microwave-absorbent material such as particulate carbon; as a result of microwave heating, they are then thermally cracked in the absence of oxygen into smaller hydrocarbon chains. The resulting gaseous products are subsequently recondensed into liquid oils of different compositions depending on the features of the input substances and reaction conditions. The use of microwave radiation as a heat source is known to offer additional advantages over traditional thermal heat sources and the combination of carbon-based material and the novel use of microwave heating in pyrolysis processes is of increasing interest as reflected by considerable recent research. Microwave systems show a distinct advantage in providing a rapid, energy efficient, and targeted heating process compared to conventional technologies, thus facilitating increased production rates and decreased production costs. Moreover, thermal energy is targeted only to microwave receptive materials and not to gases within the heating chamber or to the chamber itself. It can promote certain chemical reactions by selectively heating the reactants, leading to a more uniform temperature profile and improved yield of desirable products.

2.4 Methods followed by different researchers

Orhan Arpa, et al [3], In this study, waste lubrication engine oil samples were purified from contaminants, and the clean oil samples were blended with additives of sodium carbonate (Na₂CO₃), lime (CaO) and zeolite. The oil samples with the additives were heated in the reactor and exposed to pyrolytic distillation separately. They were exposed to thermal and pyrolytic action in order to convert them into a diesel-like fuel during the heating process. After that process, typical characteristics of the fuel, such as density, viscosity, flash and fire point, sulfur content, heating value and distillation temperatures were tested.

Table.2.1 Properties of diesel fuel and DLF obtained in the study.

Properties	Diesel fuel	(Diesel like fuel) DLF
Density at 15 °C (kg/m ³)	820-845	818
Viscosity at 40 °C (mm ² /s)	2-4.5	3.49
Flash point (°C)	>55	57
Sulfur (ppm)	50	3500
Water (mg/kg)	<200	130
Lower heating value (kJ/kg)	42,700	42,500
Temperature at 250°C, max. volume (% v/v)	65	20
Temperature at 250°C, min. volume (% v/v)	85	90
Volumat 95%, max. temperature(°C)	360	360

Findings:

1. Characteristics of the DLF, such as density, viscosity, flash point, sulfur content and heating value were tested and found to be close to the values of the diesel fuel used in the present study.
2. Utilization of Na₂CO₃ as an additive was not useful from the point of distillation temperature variation.
3. Density and flash point increase but sulfur amount decreases with the increasing of additive amounts. The lowest density, flash point, sulfur of the fuel samples were obtained by using CaO.
4. The most suitable distillation curve was obtained when CaO was used as an additive with a ratio of 2% after 30% amount of the sample.
5. The DLF was obtained as 75% of the filtered waste automotive oil. Its distillation curve increases slowly and indicates characteristics similar to diesel fuels used in diesel engines.

A. Demirbas [4], The experiment of the pyrolysis of waste lubricant oil samples were performed in a laboratory scale apparatus. The waste lubricant oil samples were treated with 3% sodium hydroxide solutions in a separatory funnel and then washed with water before pyrolysis. Alumina and zeolite catalysts (5% by weight of used sample) were used in the pyrolysis experiments. The catalysts were treated with 10% sodium hydroxide solutions before using. The pyrolysis products were collected within three different groups as condensable liquid products, noncondensable gaseous products, and solid residue.

The yields of liquid products, called “waste oil gasoline,” increase with increasing temperature. The yield of liquid product sharply increases between 570 K and 620 K in an alumina catalytic run. The yields from alumina catalytic pyrolysis were 6.6, 14.7, 22.2, and 41.8% at 275, 505, 569, and 620 K, respectively. In this study, the properties of liquid products obtained from catalytic pyrolysis are similar to gasoline. Octane number of the waste oil gasoline (96) is higher than that of gasoline (89). Flash point of waste oil gasoline (245 K) is lower than that of gasoline (249 K).

Su Shiung Lam et. al [5], used waste automotive engine oil was treated using a microwave-induced pyrolysis process, with the intention of assessing the suitability of the process in recovering valuable products from this otherwise difficult to dispose of waste. The resulting pyrolysis gases were condensed into liquid oil. Temperature was shown to have an important effect on the overall yield and formation of the recovered oils. The recovered liquid and gaseous pyrolysis products contained various light hydrocarbons which could be used as a valuable fuel and as an industrial feedstock. Our results indicate that microwave pyrolysis shows extreme promise as a means for disposing of problematic waste oil. The recovery of commercially valuable products shows advantage over traditional, more destructive disposal methods, and suggests excellent potential for scaling the process to the commercial level. This anaerobic thermal treatment uses a microwave-heated bed of particulate carbon, and has been shown to be an effective method of recovering useful chemicals present in wastes.

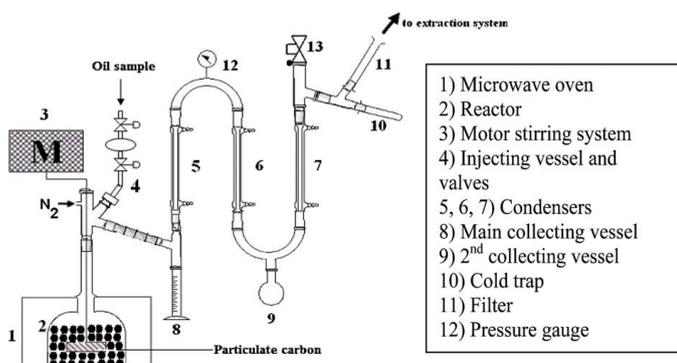


Figure.2.1 Schematic layout of bench-scale microwave-induced pyrolysis system.

One kilogram (kg) of carbon was placed into the quartz reactor. The apparatus was assembled as in Fig.2.1, and nitrogen gas was vented through the apparatus at a flow rate of 0.2l/min. A complete purge of air was ensured by washing out the system for at least 10min before heating. The bed of carbon particles was stirred by the agitator at 6rpm. The carbon was heated to temperatures ranging from 250 to 700°C, and maintained within 1% of the target temperature by computer control. The microwave-heated pyrolysis generated a 85-88 wt% yield of a condensable pyrolysis oil with a low sulphur and

oxygen content, and a density and calorific value comparable to traditional liquid fuels derived from fossil fuel.

Microwave induced pyrolysis process of waste automotive oils produces significant amounts of valuable products gaseous hydrocarbons with light olefins, and liquid hydrocarbon oils containing BTX and benzene derivatives. Increasing the temperature was found to increase the production of light gaseous and aromatic compounds, although the amount of liquid products was lower at higher temperatures. Overall, temperature has a significant influence on the overall yield and formation of the recovered pyrolysis gases and liquid oils. Valuable products were obtained from pyrolysis of the waste oil, and the microwave pyrolysis process showed improved cracking reactions compared with conventional pyrolysis processes. Microwave-heated pyrolysis offers an exciting green approach to the treatment and recycling of waste automotive engine oil. Both N₂ and waste oil flow rates were found to have effects on the fraction of original waste oil converted to pyrolysis gases, pyrolysis oils, and residues.

3. EFFECTS OF PYROLYSIS OIL ON IC ENGINE

3.1 Effects on Performance

O. Arpa, R. Yumrutas b, M.H. Alma[6] an experimental investigation was carried out to determine the effects of gasoline-like fuel (GLF), and its blends with turpentine with ratios of 10%, 20%, and 30% on the performance and emission characteristics of a gasoline engine. The GLF was obtained from waste lubrication engine oil by the method of pyrolytic distillation as shown in figure 2.2. The aim of this experimental study was to investigate effects of the fuel obtained from waste lubricant engine oil and named as gasoline-like fuel (GLF) and its blend with three different turpentine amounts on performance of SI engine and its exhaust emission. In the recycling system, two fuels to be used in engines were produced by applying pyrolytic distillation. The fuels named as gasoline-like fuel (GLF) and diesel-like fuel (DLF) were obtained from waste lubrication engine oil.

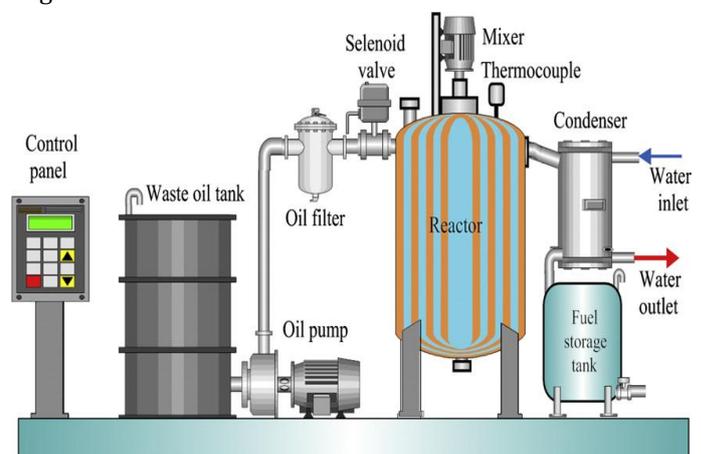


Figure.2.2 Schematic representation of the fuel production system.

In the recycling system, 80 wt% of the total waste lubrication oil was converted into useful fuel in the pyrolysis process. Light and heavy fuels are commonly used in SI and diesel engines, respectively. Since characteristics and distillation curves of both fuels are similar to those of gasoline and diesel fuel, the light and heavy fuels are named as gasoline-like fuel (GLF) and diesel-like fuel (DLF), respectively. It is necessary to determine the effects of fuels on performance and emissions of engines in order to decide whether the fuels or their blends with other fuels will be used in engines as fuels or not, so they were investigated on SI engine.

Increasing amount of turpentine in the GLF sample had positive effects on the performance parameters. It was observed that the GLF and blends of the GLF with the ratio of 10%, 20% and 30% of turpentine could be used as a fuel in the SI engines without any problems according to the test results. When the turpentine percentage in the GLF is increased, then the T_b , B_{mep} and η_{bt} increase, and B_{sfc} decreases. Decrease in the B_{sfc} and increase in the other parameters depend on relationships between the brake power and these parameters. Due to the fact that the T_b , B_{mep} and η_{bt} are directly proportional, but B_{sfc} is indirectly proportional with the engine brake power. At the engine speed of 2500 rpm, the T , B_{mep} and η_{bt} reach to the highest values, and the B_{sfc} arrives to the lowest values for all types of the fuels. The maximum engine torque for the pure GLF fuel and the other three blends of 10%, 20% and 30% turpentine were obtained as 98.3, 98.97, 99.65 and 101.1 Nm at 2500 rpm, respectively. As a result, thermal efficiency increases with increasing amount of turpentine in the GLF sample. The corresponding maximum values of the η_{bt} for the same fuels and the engine speed are 36.84, 37.52, 38.13 and 38.92%, respectively. The Lowest value of the η_{bt} (36.84) is obtained when pure GLF is used in the engine. For the same running conditions, B_{sfc} values decrease gradually and approximately from 222, to 214, 208 and then to 200 g/kWh, respectively. It can be possible to explain that higher density and calorific value of the turpentine than that of the GLF causes the increments in the performance parameters of T_b , B_{mep} and η_{bt} , and decrements in the B_{sfc} , because density and calorific values of the turpentine blends are higher than those of the GLF.

Orhan Arpa, Recep Yumrutas, Zeki Argunhan [7] Performed experimentation on diesel like fuel (DLF) on engine performance and exhaust emission. It was observed from the test results that about 60 cc out of each 100 cc of the waste oil are converted into the DLF. The thermal and physical characteristics of the DLF are close to those values of a typical diesel sample. Moreover, its distillation temperature increases gradually, and its behavior is similar to that of diesel fuels used in engines. Results of these properties correspond to those given in Turkish standard values except for the sulfur amount. It was observed that the produced DLF can be used in diesel engines without any problem in terms of engine performance. The DLF increases torque(T), brake mean effective pressure(B_{mep}), brake thermal

efficiency(η_{bth}) and decreases brake specific fuel consumption (B_{sfc}) of the engine for full power of operation.

The authors establish that T , B_{mep} , η_{bt} and B_{sfc} trends for the DLF and diesel fuel are similar in nature. It is known that T and B_{mep} are directly proportional but B_{sfc} is indirectly proportional with the engine brake power given. The T , B_{mep} , and thermal efficiency values obtained for DLF are slightly higher than those obtained for diesel fuel, but B_{sfc} is lower in all revolutions. Average increases of the T and B_{mep} values are approximately 0.69% for the DLF. This was due to high distillation temperature of the DLF than diesel fuel. The maximum T and B_{mep} values obtained from the measured data for the DLF and diesel fuel in 2000 rpm are 33.86 and 33.71 Nm, 1048.21 and 1043.38 kPa, respectively. The corresponding thermal efficiency and B_{sfc} for DLF and diesel and the engine speed are 40.68 and 37.88%, 213.23 and 224.52 g/kWh respectively. After the maximum and minimum values of these parameters they decrease and increase with the engine speed gradually.

Orhan Arpa, Recep Yumrutas [8], Experimental investigation on engine performance and exhaust emission of a gasoline engine fueled by Gasoline like Fuel (GLF) was performed in this study. The GLF was obtained from waste lubrication oil (WLO) using the pyrolytic distillation method in presence of calcium oxide (CaO) 2, 4, 6, 8, and 10 wt% to remove sulphur in the oil. The experimental results indicated that the CaO at 2 wt% had the highest effect on decreasing the amount of sulphur content in the lubrication oil. Fuels produced using 2 wt% CaO were separated into two parts which were light fuel with 20 wt% and heavy fuel with 60 wt% of the total WLO. The light fuel, referred to as GLF and gasoline samples are used to investigate the effect of the GLF on performance and emissions of a 1300cm³ spark ignited engine manufactured by Fiat.

Table.2.2 Some characteristics of the GLF and unleaded gasoline.

Properties	Test Method(ASTM)	GLF	Gasoline
Density at 15°C (kg/m ³)	D1298	740	780
Flash point (°C)	D93	25	43
Lower heating value (kJ/kg)	D270	43,000	43,890

Variations of engine T , P_b , B_{mep} , η_{bt} and B_{sfc} with engine speed shows that the values of GLF are higher than the values of gasoline used, and values of the B_{sfc} are lower than the value of gasoline. The highest T , B_{mep} and η_{bt} for the GLF and gasoline are obtained as 98.3 and 93.8 Nm, 952.4 and 908.2 kPa, and 36.8% and 29.4%, respectively. Corresponding values of the B_{sfc} for the same fuels and the engine speed is approximately 222 and 281 g/kWh, respectively. All of these performance parameters (T , B_{mep} and η_{bt}) for the GLF and for all engine speeds are higher than those of gasoline fuel with an approximate value of 5%. It is

seen that these three parameters for the GLF are better than those of the gasoline. This is an important criterion that makes the GLF advantageous.

As a result, it is observed that ignition timing, air-fuel ratio, characteristics and higher distilled temperatures for the GLF give better performance parameters than the gasoline. Therefore, T, Bmep and η_{bt} increase and Bsfcc decreases. The experimental study test results have clearly shown that the GLF has a positive effect on the performance parameters of the engine, and it can be used as a fuel in the gasoline engine without any problems according to these test results.

3.2 Effects on Emission

O. Arpa, R. Yumrutas b, M.H. Alma[6], In this experimental study, exhaust gas temperature and the engine emission parameters such as, NO_x , carbon monoxide (CO), carbon dioxide (CO_2), and unburned hydrocarbon (HC) were obtained by using the gas measuring device. The exhaust temperature increases with the engine speed and amount of turpentine in the GLF. The highest value of exhaust gas temperature is measured as 450°C by using GLF, whereas it is found to be 519°C by using blend of GLF and 30% turpentine for the engine speed of 3500 rpm. The main effect of 10%, 20% and 30% turpentine additions to GLF on pollutant formation is that values of the CO_2 and NO_x increase, while that of CO decreases. The CO_2 and NO_x and CO values reach the highest and the lowest points, respectively at a speed of about 2500 rpm. The increasing of the CO amount after the inflection point is the result of increasing temperature of the combustion chamber, deficiency of oxygen at high speed, and less time available for completion of combustion. Unburned hydrocarbon emission test results for GLF and blend fuel samples with 10%, 20% and 30% of turpentine. It is observed from that HC emission gradually increases with turpentine amount. Atomization and mixing of a fuel depends on the physical properties of the fuel such as density, viscosity, surface tension and this affects HC emission.

Orhan Arpa, Recep Yumrutas, Zeki Argunhan [7], When the DLF sample is used, the exhaust temperature is higher than that of the diesel sample, and it increases with the engine speed. The measured exhaust temperature varied between 414°C and 515°C for the DLF as compared to 397°C and 477°C for diesel indicating remarkable variation in exhaust temperature. The results concerning the exhaust emissions of SO_2 , CO, NO_x and O_2 measured by exhaust analysis device. The CO and NO_x emissions from the engine operated with the DLF are higher than those of diesel for all engine speeds. The NO_x and CO values reach the highest and the lowest points, respectively at a speed of about 2200 rpm. Illustrate that these emissions decrease with engine speed of up to 2200 rpm, and then increase again with the engine speed. Emissions of CO from a diesel engine mainly depend upon the physical and chemical properties of the fuel, air-fuel ratio and engine temperature, deficiency of oxygen, and the fact that less time is available for the completion of

combustion, all of which cause incomplete combustion. Air-fuel ratio is the most essential parameter which leads to emissions of CO, CO_2 and HC.

Orhan Arpa, Recep Yumrutas [8], although amounts of CO and HC for GLF are lower than those of gasoline, CO_2 emission is higher than that of gasoline. Combustion conditions concerning the exhaust products are very important. CO emission depends on many parameters such as chemical structure and homogeneity of the fuel, insufficient time of burning, low and high temperatures and insufficient air. Insufficiency of air is the most important parameter, for it leads to the rejection of the CO from the exhaust without being converted into CO_2 . The lower HC present in the exhaust gases is a desired condition, since the HC and CO in the exhaust show that unburned hydrocarbons are rejected to the atmosphere. Most of the HC results as a consequence of an unburned fuel-air mixture while the other source is lubricating engine oil and incomplete combustion, and the HC increases with increasing ignition delay.

3. CONCLUSIONS

Based on the reviewed paper it is concluded that the fuel can be extracted from waste automotive oil using different pyrolysis process. The performance and emissions tests of waste automotive Pyrolysis oil shows that it can be used as fuel in internal combustion engines without any engine modification. The pyrolysis oil represents a good alternative fuel for internal combustion engine and therefore must be taken into consideration in the future use. The thermal and physical characteristics of the diesel like fuel (DLF) and gasoline like fuels (GLF) are close to those values of a typical diesel and petrol sample. Its behaviour is similar to that of diesel and petrol fuels used in engines.

A number of advantages of microwave heated pyrolysis process were found over other processes that use traditional thermal heat sources. It is evident that microwave-induced pyrolysis has huge potential as a means of recovering commercially valuable products from problematic waste automotive oil. Thus there is scope of further research to extract maximum yield of pyrolysis oil which will give better performance characteristics on internal combustion engine.

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